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A Theory of Inference Derivation for Qualitative Data: Development and Test with Application to Criminal and Terrorist Detection

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For this research, the authors developed a process for modeling group decision making. The models are based on analysis of the options selected by members of the group working alone or with others in "committees." The selection process is represented as exclusive, exhaustive category schemes (facets) to describe the options available and then the choice of alternatives using these facets. The analysis of these generation and selection processes is modeled using nonmetric multidimensional scaling procedures.

A series of studies shows that the facet analyses model effectively many aspects of group decision making when the choice criteria involved are essentially qualitative. The application of the facet framework therefore provides a theory of how groups make inference by combining the option selection of their individual members.

Aspects such as dominance, alliance, opposition, and involvement, issue salience and relevance and can all be made operational within the facet models of a given group. Studies indicate that by feeding back to a group the results of this type of modeling "committee"
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effectiveness may be enhanced. The theory provided a basis for creating an
online, interactive group decision support system.
     Applications of the modeling process to actual decision problems in
relation to serial sexual assaults, hijacking, and research grant allocation,
as well as student housing selection serve to illustrate the great range of
problem solving groups that the theory and a system based on it can assist.
     The following are major findings from the studies:

● The system can model both the task and process of group decision making.

● The model can identify possible alliances and opponents in the decision
   making group.

● Measurement of group perceptions can be fed back to the decision
   makers, illustrating, for example, the perceived effectiveness of
   leadership and the experts' satisfaction with the representation of
   their views.

● The model has proved particularly successful in deriving inferences
   in linking of serial crime and can represent actual links between
   crimes derived from the opinions of experts more accurately than the
   experts can themselves in their group decisions.

● The representational techniques can be applied to unstructured accounts
   of terrorist activity, demonstrating similarities and differences in
   behavior that can be associated with either "personal" or "political"
   skyjacks and with terrorists.

A THEORY OF INFERENCE DERIVATION FOR QUALITATIVE
DATA: DEVELOPMENT AND TEST WITH APPLICATION
TO CRIMINAL AND TERRORIST DETECTION

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A THEORY OF INFERENCE DERIVATION

GENERAL SUMMARY

A process for modelling group decision making is developed. The models are based upon the analysis of the options selected by members of the group working alone or with others in "committees". The selection process is represented as the generation of exclusive, exhaustive category schemes (facets) to describe the options available and then the choice of alternatives using these facets. The analysis of these generation and selection processes is modeled using non-metric multidimensional scaling procedures.

A series of studies show that the facet analyses do indeed model effectively many aspects of group decision making, where the choice criteria involved are essentially qualitative. The application of the facet framework therefore provides a theory of how groups make inferences by combining the option selection of their individual members.

Aspects such as dominance, alliance and opposition, involvement, issue salience and relevance can all be operationalised within the facet models of a given group. Studies indicate that by feeding back to a group the results of this type of modelling of their activity may be very productive in enhancing "committee" effectiveness. The theory therefore provides a basis for creating an on-line, interactive group decision support system.

Applications of the modelling process to actual decision problems in relation to serial sexual assaults, hi-jacking and research grant allocation, as well as student housing selection serve to illustrate the great range of problem solving groups which the theory and a system based upon it can assist.

The Following Major Findings from the Studies May be Highlighted:

1. The system can model both the task and process of group decision making.

2. The model can identify possible alliances and opponents in the decision making group.

3. Measurement of group perceptions can be fed back to the decision makers illustrating for example the perceived effectiveness of leadership and the experts' satisfaction with the representation of their views.

4. The model has proved particularly successful in deriving inferences in linking of serial crime and can represent actual links between crimes, derived from the opinions of experts, more accurately than the experts can themselves in their group decisions.

5. The representational techniques can be applied to unstructured accounts of terrorist activity, demonstrating similarities and differences in behaviour which can be associated with either 'personal' or 'political' skyjacks, and with different terrorist

A THEORY OF INFERENCE DERIVATION FOR QUALITATIVE DATA: DEVELOPMENT AND TEST WITH APPLICATION TO CRIMINAL AND TERRORIST DETECTION

A THEORY OF INFERENCE DERIVATION

BASED ON A MODEL OF GROUP DECISION MAKING

(With Special Application to the Production of an On-Line, Interactive, Computer Aided, Group Decision Support System)

REVIEW OF REPORT

In the process of developing a theory for inference derivation from qualitative data it became apparent that most such inferences evolve out of discussions between people and are validated by group processes. Any fruitful theory therefore needs to address directly how these group processes could be facilitated by modern computing procedures. In order to produce such procedures the group process of inference derivation itself needs to be modeled. The following studies describe the development of such models and their implications for an emerging group decision support system.

FOCUS

The focus of the project is the establishment of the theoretical and technical basis for the development of a new system for decision support. The system is aimed at structuring qualitative material for group decision making with particular application in criminal and terrorist detection.

The generation of a scientific basis for terrorist and criminal investigation has a number of particular problems which the new system directly confronts;

1. The material available from which to derive inferences is mainly qualitative and so not amenable to conventional decision structuring.

2. This material is often incomplete and of a format which precludes analysis based on traditional statistical models.

3. Much of the expertise in these areas is encapsulated within the experience of key individual decision makers. This requires specific elicitation techniques which draw on this implicit knowledge.

4. The scale of investigation into criminal and terrorist incidents requires the collaboration and interaction of a number of key individuals. This interaction therefore requires that the system works within existing group structures and accounts for the inherent social psychological processes of these groups.

OUTLINE:

The following report describes a series of studies which have been carried out in order to establish the basis for a computerised system for decision support. In combination these studies detail the theoretical and technical developments which have been made during the period of the research. For completeness, studies reported in earlier interim documents are

included to provide the necessary background to later work. The work relates directly to three important areas of current research.

1. The elicitation of different types of knowledge. This includes both the knowledge of individual and groups of experts and the knowledge which exists within a data set. The facetted sorting procedure is developed to generate qualitative facets of knowledge from experts. In the same way, facets relating to relationships between aspects of behaviour are content analysed from material such as witness statements. This allows data relationships to be established which can be drawn on to provide a parallel system of expertise inherent within the qualitative data.

2. Techniques for the analysis of qualitative data. Two analysis procedures are explored in detail. Multi-dimensional Scalogram Analysis (MSA) is used to represent material which is purely qualitative and categorical and Partial Order Scalogram Analysis (POSA) is used where qualitative distinctions contain a quantitative order.

3. Research into the way that data representations can be used to facilitate the group processes of decision making. Issues concerning the communication and collaboration between members of the expert group are addressed, along with the impact of key individuals within a hierarchical group structure.

A New Perspective on Decision Support

These three areas of research combine to present a new perspective on decision support. This approach takes important steps beyond current thinking behind expert systems and computer based support by considering issues overlooked by previous systems;

1. The impact of interpersonal interactions on the system in use within the normal context of decision making. The new system acknowledges the psychological processes which occur when a decision support system is used within a 'natural' applied setting.

2. The need for the representational techniques to work on-line in such a way that both developments in the structure of the problem and the structure of the group can be incorporated into a dynamic system for decision support.

3. The need to represent aspects of background and expert knowledge in an immediately 'readable' form. By structuring and presenting information in a simple visual format the system provides support that people can understand and act upon.

The most parsimonious attributes are elements of exhaustive, exclusive category schemes, i.e. sub-sets of defined sets that cover all entities to be classified. These category schemes are know as "Facets". Every set of entities can be classified by a number of logically distinct facets.

Decision options are, thus, described in terms of categorical differences and similarities on a series of attributes. The attributes are drawn from facets, the attributes being elements of implicit or explicit facets.

Thus, for example, incidents can be classified on a number of facets describing their characteristics.

For example, whether a hijack occurred on a

[A] $\begin{bmatrix} 1. \text{ International flight} \\ 2. \text{ Domestic} \end{bmatrix}$

where shots were fired   [B] $\begin{bmatrix} 1. \text{ Spontaneously} \\ 2. \text{ When forced} \end{bmatrix}$ and the hijackers

[C] $\begin{bmatrix} 1. \text{ Did no damage to the plane.} \\ 2. \text{ Threatened damage} \\ 3. \text{ Caused Damage} \end{bmatrix}$

Each incident can then be classified in terms of its profile of characteristic on each facet or attribute (eg A_1, B_2, C_3). This profile of attribute sub-categories is known as a structuple.

This type of material can then be represented using appropriate analysis techniques whereby the greater the similarity in the facet structure between two options or incidents the closer

together they will be represented in geometric space. Thus an incident with structuple $(A_1 B_1 C_1)$ will be closer in the space to $(A_1 B_1 C_2)$ than one represented as $(A_2 B_2 C_3)$.

This model can then be extended to expert knowledge whereby the facets of importance are generated by the group members and options assigned to elements of those facets. In this way the relationships between the options can be represented. Further, since the facets generated are directly attributable to individuals in the expert group, the relationship between different individuals' assignment of the options enables the model to be used for group representation, and the comparison of viewpoints of individuals within the group.

Basic Principles

The system is therefore based on five basic principles;

1. That individual decisions are based on the assignment of options to attribute sub-categories (elements) which reflect their respective qualities on each of a series of categorisation schemes (facets).

2. That the facets are criterion referenced. That is, that in terms of option selection there are acceptable or desirable elements or combinations of elements and unacceptable or undesirable elements or combinations of elements.

3. That the facets are applied to a choice between the options on the grounds of their profile of attributes (structuples).

4. That it is possible to model the combination of a number of individual's classifications which represents the composite knowledge of a group. But

5. That a simple unweighted combination does not necessarily represent a true group decision which will be influenced and distorted by group processes.

A Faceted Model of Group Processes

In summary the proposed system has the following characteristics;

1. The system will interactively model the group decision at each stage from their initial classification through their discussion reflecting the developing concerns of that particular group.

2. The system will model the structure of the decision in an accessible visual format.

3. The group can consult the system to account for the facets currently under consideration by the group as a whole.

4. The system can reveals the relationships between the facets themselves. For example to find out the extent to which an element of facet A also encompasses an elements of facet B. (If three bedroomed houses have bigger kitchens; if rapists who gag their victims also blindfold them)

5. The group can draw on and compare their facet structure to those used generated by other groups working on similar problems.

6. The group can draw on a parallel system to reveals the facet structures derived from analysis of existing material in the form of the relationships within a data base.

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The contents of the report

The report is arranged as a series of studies which together detail the development of the foundation work for the new system for decision support.

Chapter One demonstrates the way in which Partial Order Scalogram Analysis (POSA) can be used to structure the type of decision data in which a number of options can be classified according to ordered differences on a number of qualitatively different attributes. The example uses the data from a university grants committee in the allocation of funding to research proposals. Analysis and representation of this material demonstrates the potential for structuring this type of decision data and the role which POSA could play in decision support.

Chapter Two describes the initial pilot studies which test the use of Multidimensional Scalogram Analysis (MSA) for the representation of decision data which is purely qualitative and categorical. Using a hypothetical decision problem and volunteers the MSA modelling

technique is described and the way in which the representations could be used to improve both the task and the process of group decision making is explained.

Chapter Three details the development of a questionnaire which measures people's experience of the decision making process, and Chapter Four illustrates the way in which the questionnaire data can be analysed in order to compare the objective summaries of the decision making groups modelled through MSA to the subjective perceptions of the group members.

Chapter Five describes a pilot study in which the MSA modelling technique is applied to a decision making problem in linking of serial crime. Three police officers took part in the study and the results demonstrate the potential for applying the technique to police decision making. The main study is reported in Chapter Six, presenting the results of five police decision making groups dealing with the linking of serial crime. The study shows the way in which representation using MSA portrays the relationships between incidents committed by different attackers on the basis of aspects of their behaviour. The extent to which the MSA models both the officers' decisions and the true connections between the incidents considered.

Finally, Chapter Seven considers the way in which qualitative aspects of the behaviour of hijackers can be used to draw inferences about the organisation to which they belong. Using the same principles of those used in the linking of serial rape, the analysis techniques are demonstrated in relation to qualitative descriptions of the incidents.

For reference purposes, previous documentation from interim reports on the technical background to the representational system are provided as appendices to the main report.

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CHAPTER ONE:

STRUCTURING DECISION DATA. USING POSA TO ALLOCATE FUNDING TO RESEARCH PROPOSALS.

Using existing data from a university grants committee, the potential contribution of information structuring using POSA is explored. Using the data generated through the current system of rating the proposals, different types of structuring are demonstrated which would have the potential of improving the decision making process both for the individual and for the group.

CHAPTER ONE:
Structuring Decision Data. Using POSA to Allocate Funding to Research.

1.1.1 Introduction

Early work demonstrated that POSA could play a role in identifying differences in expert judgement with respect to a number of decision options, which could be developed into a process for feedback to expert decision making. The procedure maps the experts' judgements of a number of decision options according to quantitative differences on a number of qualitatively different attributes and allows the areas of disagreement between groups of decision makers to be pinpointed.

The following research awards example illustrates how POSA can be usefully applied to a group decision making situation in which a decision rests on the opinion of a number of experts. In particular POSA is used because the evaluative techniques used by the research awards committee uses quantitative assessments of projects on qualitatively different criteria, for which POSA is a particularly suitable means of representation. The way in which POSA could be fruitfully fed into the group process is demonstrated using data which already exists, and developed further in its application and implications.

1.1.2 Background

In a similar way to many interdisciplinary research committees, when an application for a research award from University of Surrey is made, the proposal is evaluated in competition with a number of other proposals. The proposals are judged on ten predetermined criteria by six raters. The raters are senior members of the University staff, and are selected from different academic backgrounds. On the basis of the sum of the scores on the ten predetermined criteria, each rater rank orders the proposals. These rank orders are then used within a committee discussion to decide on the 'best' projects to which to award available funds. The task of the research committee, then, is to consider as many as thirty applications and select the half dozen or so that their research allocation can fund.

1.1.3 A Matrix Representation of Group Decision Making

Previous reports have established the way that the parameters of a group decision can be structured in the form of a matrix. Once the content of the problem is defined in the form of a matrix, the relationships within the data can be structured using the representational system. Preliminary explorations have been very encouraging in supporting the hypothesis that it is of great help to a group of decision makers to have a representation of critical aspects of their decision matrix presented to them.

The task of a committee, considering say thirty applications, can be appreciated by the fact that if a mere ten minutes discussion were given to each application then the meeting would take 5 hours. However, if they could concentrate on, for instance, the best ten applications then, on average half an hours discussion can be given to each. However, experience shows

that a simple addition of overall ratings of each application cannot be used to select the best because of qualitative differences between members of the committee. If person 2 thinks very favourably of an application and person 2 is against it, their combined scores hide profound dissension rather than summarising an average level of support. A procedure that allows these differences of opinion to be made overt to the group could greatly assist the focusing of discussion on matters of substance.

In order to facilitate this modelling of the group process the qualitative as well as the quantitative differences between people need to be represented. A matrix representation of the opinions of each person in the group is a step towards this modelling.

Early work considered the way a set of entities [E] such as crimes (E1, E2,....En) can be classified on a set of qualitative attributes [A] (A1, A2, ...An), each attribute taking one of a set of values. In this framework it is then possible to describe the data set [ExA] where each of a number of entities are described by a profile of characteristics according to their values on attributes A1 to An.

The realisation that the data could also incorporate different expert views allowed for the inclusion of a further facet P of people (P1, P2 ....). Adding this facet to [ExA] means that for any element of E, or any element of A there is a data matrix [AxP] or [ExP] respectively. Therefore the representation of the [AxP] or [ExP] matrix is a representation of certain aspects of the group decision process.

Further it has been possible to structure the data in such a way that all three parameters of the group decision process can be included in the representation. Thus each person's classification of each element on each attribute can be represented in the same matrix [EPxA].

These three types of matrix definitions of group decision making are demonstrated in the following sections. The example used is the data from the university grants committee which has proved amenable to such decision structuring.

1.1.4 Applications of POSA

The examples are presented in increasing order of the complexity of the data manipulations.

> ### i) The Rank Order Data ([ExP] for A (evaluation))
> **In terms of different people's evaluations.** The first example shows how POSA can be used to represent the data as it is currently used by the group to make the decision. That is in terms of the six group members' rank orders of the submitted proposals. In this case the representation will show the combination of the six people's rank orders as a composite, as well as the way each individual's rank orders make up that composite.

> ### ii) The Individual Ratings ([ExA] for P(Rater))
> **In terms of their attributes.** POSA is used to represent an individual raters' judgement of the proposals prior to the stage of rank ordering them. The current system produces rank orders from the sum of the scores on ten criteria. The POSA representation maintains this quantitative aspect of the data but also

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provides representation of the qualitative differences between the proposals. For example, by distinguishing between two proposals with the same sum totals in terms of their strengths and weaknesses on the different dimensions. This expands the current system by allowing the expert to judge the proposals in terms of the combinations of qualities which he feels to be important rather than by a simple additive measure.

iii) All Raters' Judgements on all Attributes ([EPxA])

Finally, it is possible to use the POSA to examine the overall view of all the projects by all the raters. In this way the systems of judgement used by the raters can be compared to identify any consistencies. Two types of consistency are considered; consistencies which are characteristic of the way the individual raters view all the proposals, and consistencies between the raters in terms of their views of the proposals.

1.2 The Rank Order Data ([ExP] for A (evaluation))

1.2.1 Introduction

The first example takes the data which the raters currently use during the group discussion, i.e the rank orders of the proposals. By combining the six raters' assessments of the proposals it is hypothesised that the group decision itself can be modelled using POSA. POSA represents the logical combination of their views, which should be consistent with their final decision provided they are working in a democratic way. However, because POSA maintains the individual viewpoints of the members, the extent to which each member's views were represented in the decision can also be assessed.

1.2.2 Construction of the Data Set

The data used were the rank orders of the proposals as constructed by each of six raters on the basis of the sum of scores they had assigned to each proposal on ten criteria. Each set of ranks was collapsed into five categories from the highest regard (1) to the lowest (5). The data matrix indicates each rater's evaluation of each proposal.
The format of the data matrix is shown below:

For An	People (P) (Raters)					
Entities (E) (Proposals)	A	B	C	D	E	F
1	5	5	5	3	1	1
2	4	4	4	3	2	3
3	1	1	1	3	2	1
4	1	4	3	2	5	5
n	....					

Each row is known as a 'profile', of scores, and is comprised of the position in which each proposal was placed in the ranking by each rater. The matrix is therefore of the form (ExP) with respect to An; entities are judged on a single attribute (overall worth) by a number of people.

1.2.3 Interpretation of the POSA Plots

The differences between the profiles can be characterised in two ways. Firstly they can be thought of in quantitative terms, ie the sum of the scores across the row. Such a measure would indicate the raters' overall response to the project as a group, a high total indicating that they thought it a poor project and a low total indicating a better opinion overall. This is therefore a measure of the opinions of the raters as a group.

In terms of the POSA plots, these quantitative similarities and differences are represented by the position of the points along the x+y or 'joint' axis of the POSA plot. Figure 1 shows a set of example profiles which systematically vary on the quantitative scale, and are thus plotted along the x+y axis.

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                                          111  *



                    *222




       *  333
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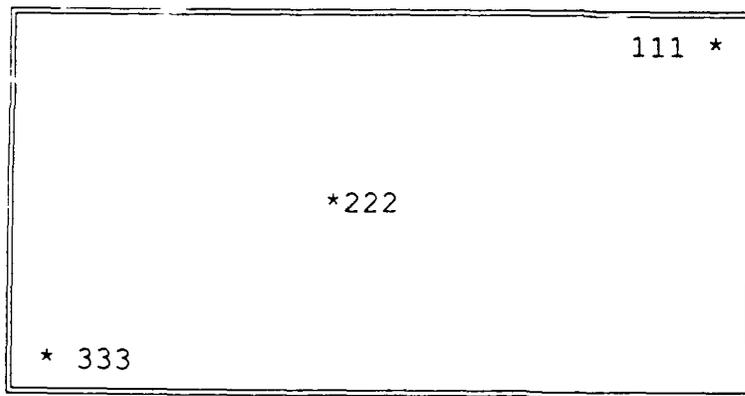
Figure 1. Sketch diagram of a POSA plotting
quantitatively different profiles.

The qualitative differences between the projects are represented by the lateral, or x-y axis. Figure 2 would represent a set of profiles which did not vary much quantitatively, ie the sum of the profiles were the same, but did vary qualitatively. This qualitative variation is a result of different raters' opinions of the projects. Clearly, they represent serious differences of opinion between members of the committee.

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│ │ *321                                     │ │
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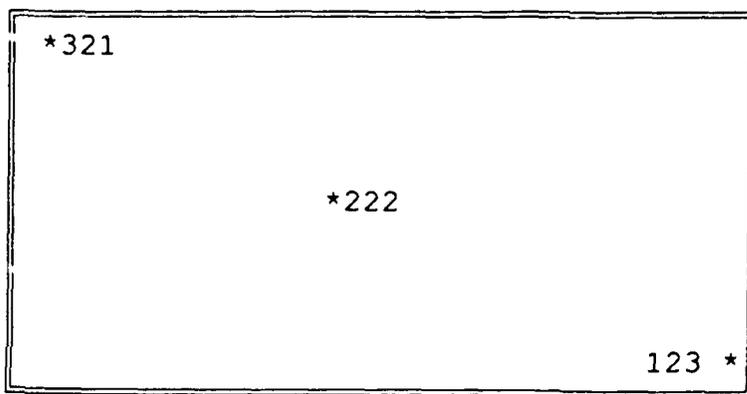
Figure 2. Sketch diagram of a POSA plotting qualitatively different profiles.

In a group decision where the projects can be ordered in terms of simple quantitative attributes and where the experts agree that they are of a varying worth, the decision process would be an easy one, simply drawing the line at the level at which the funds were sufficient to cover the projects.

Lack of variation on the x-y or lateral axis thus indicates agreement between members of the committee. On the other hand, the configuration of points shown in Figure 2 would suggest that the group as a whole feel similarly about all of the projects on the quantitative dimension. When the opinions of the individuals who comprise the group are taken into account the variations in their judgements are revealed. In a situation such as this the decision making process would be extremely difficult, since no real consensus exists between the experts.

It is particularly important to address the issue of qualitative variation. Whilst the sum total of each of the rater's opinions may be representative of the group as a whole, it does not represent the views of the individual members. If consensus were required within a decision making group, the subtle differences in opinion of the group members would be of prime importance to the decision making process.

1.2.4 Results

i) Modelling the Group Decision

Figure 3 shows the overall POSA plot of six raters' opinions of the research proposals submitted in 1990. Each point represents a proposal, and those circled are the proposals which were eventually funded.
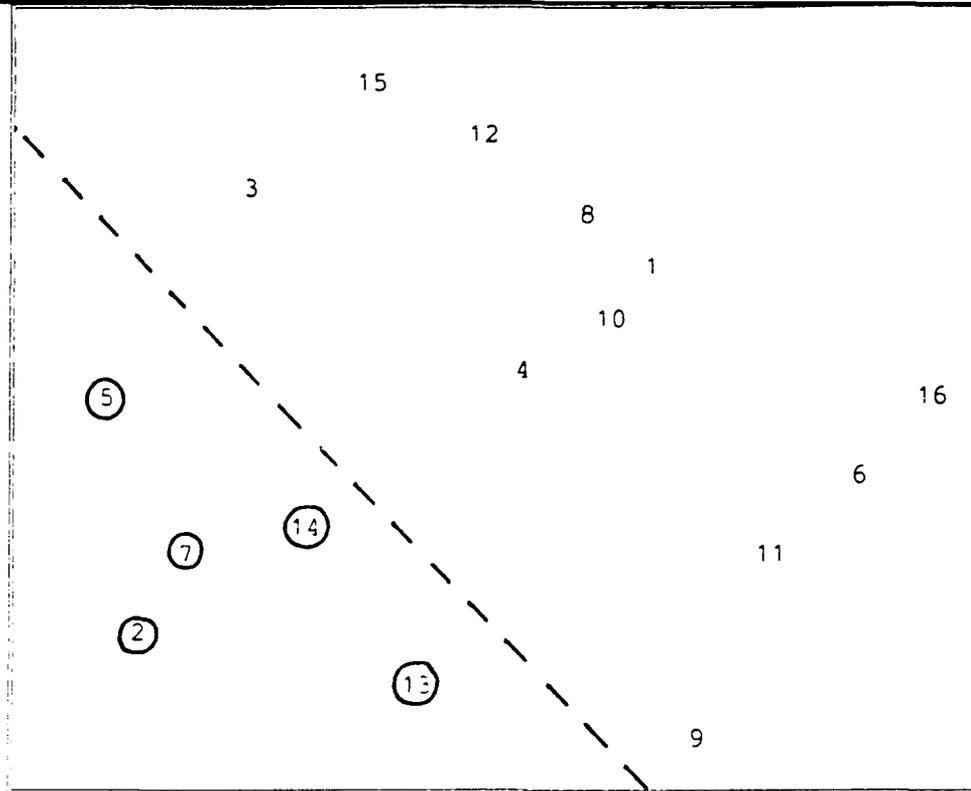
Figure 3. Overall POSA Plot showing the Positions of the Research Proposals (1990) According to the Six Raters' Rank Orders (proposals receiving funding are circled).

Figure 3 shows the scaling of the proposals according to their ranks as perceived by the group as a whole. Although no representation is used by the committee at present, they do consider the rank orders created by the group members as a basis for selecting from the proposals. It is therefore particularly interesting that the five which the committee selected at this particular meeting (circled in the plot) are those which the POSA would predict as being the most representative of the group's opinions on the basis of the rank orders. This means that the POSA does indeed model the decision making process in this case. If funding were being allocated strictly on the quantitative dimension of the projects' evaluation, then a line may be drawn according to the funding available and those projects which fall below the line would be awarded the money. Similarly, it could be predicted that if more money became available, project number 9 would be the next most likely recipient of the funding.

Therefore, the POSA has modelled the actual decision making process of the group using this type of data. If this type of representation can model what the group actually did, even though it is working with data which was created with no connection with the representational system, then it has great potential for use actually during decision making. If the group continued to structure their material using the present system, POSA would have an application in combining the rank orderings of the individual members and display a possible 'solution' for discussion.

Given the validity of such a model the situation could be foreseen where no meeting was necessary, the POSA showing that a consensus exists from which an automatic decision can be drawn.

However, more interestingly, if the system models the process which already takes place, and has a number of features which would improve the decision making process, then it could be hypothesised that those features would be of benefit to the decision making group.

The following sections of this chapter will examine different ways of representing the content of this one data set, using the raters' original score sheets. The data can be represented at a number of different levels. The first contribution that representation using POSA has, even at the least detailed level of the rank orders, is consideration of individual differences between the raters.

ii) Individual Differences

The overall POSA plot shows the combined opinions of the group. However, the 'item plots' which are also produced by the programme allow the individual contributions to the group composite to be examined too. The item plots show how each of the raters ranked the proposals, and so show exactly how their individual views combined to form the group view.

Figures 3d to 3f show these 'item plots', each plot referring to the rank order created by each of the six raters.

Each item plot shows the same configuration of points as in Figure 3. However, in place of the proposal number, the program plots the number that proposal scored from that particular rater. These plots are then divided up ('partitioned') so that the proposals are enclosed in 'regions' according to their position in the rank order. For ease of interpretation the points are labelled with proposal numbers and the regions labelled according to the score of the proposals.

The item plots for raters C, E and P partition the same way, along the joint axis, in just the same way as the decision was made (see Figures 3c, 3e and 3f). These raters have a very similar view of the projects as one another, and it would be hypothesised that they would be satisfied with the decision. For example, rater F rated projects two and thirteen amongst his best three, and projects five and fourteen amongst the second best. However, he rated project eleven highly (not chosen), and rated project seven (chosen) only moderately.

Rater E rated all the chosen proposals amongst his best, or second best, indicating that his views were well represented in the decision. However, he rated project four more highly than project thirteen, although this was eventually chosen.

Rater C's views were also well represented in the decision, and only one of the chosen proposals (five) received a mediocre rating from this individual. His opinion of proposal nine was higher than that of the group as a whole and provided the group discussion did not alter this rater's initial opinions of the projects it could be inferred that this oversight would be the only disappointment for him following the committee's decision.

In conclusion, POSA shows that the evaluations made by these three raters are based on broadly similar structures and it would be relatively easy for these raters to agree.

On the other hand, a very interesting comparison can be made between the structures

14
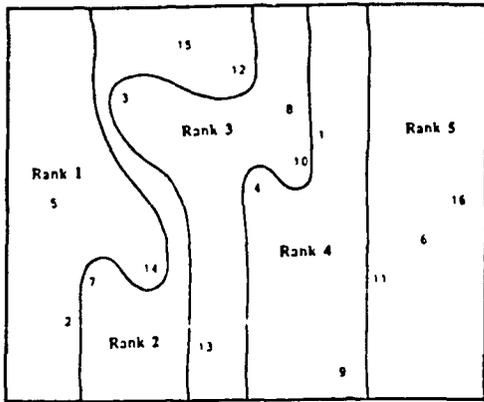
Figure 3a. Rater A
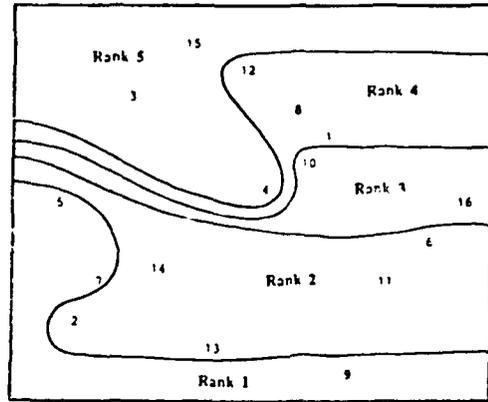
Figure 3b. Rater B
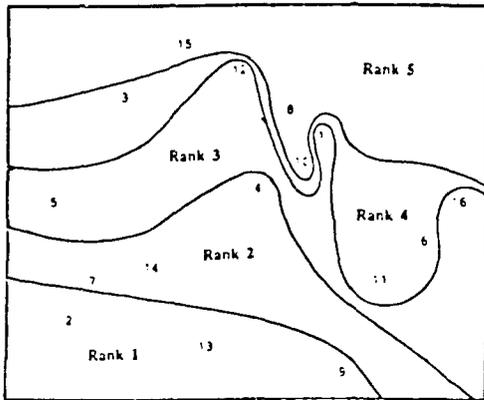
Figure 3c. Rater C
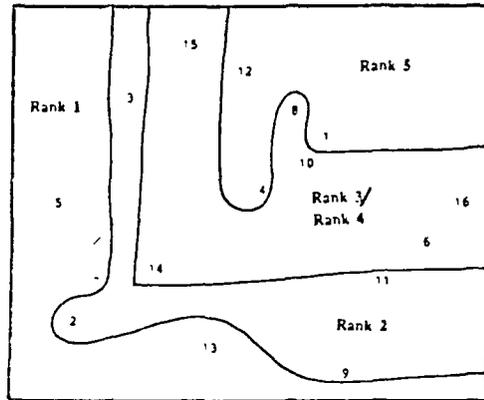
Figure 3d. Rater D
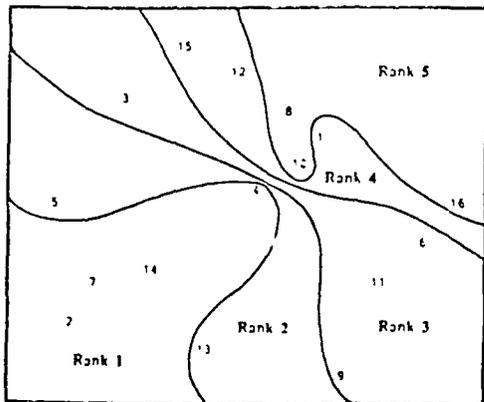
Figure 3e. Rater E
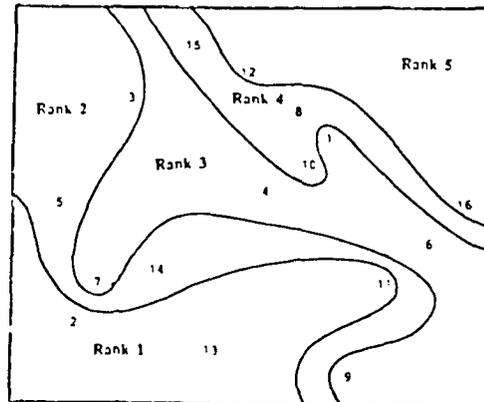
Figure 3f. Rater F

Figures 3a to 3f. POSA Plot of Research Proposals Partitioned According to Each Rater's Rank Order of Proposals.

reflecting the evaluations made by raters A and B. Although the chosen projects were considered to be among the best by both of these raters, the overall structuring of the proposals in terms of their value is quite different. Whilst these two raters agree on some of the best and some of the worst, if they had been required to agree about all the proposals, these two raters would have been found to have quite different views.

POSA represents rater B's opinions of the projects along the y axis (Figure 3b), so that whilst those at the bottom left, (chosen) are seen to be good choices for funding,
so too are those at the bottom right. The projects across the top of the plot are those which this individual rates most harshly.

In contrast, the item plot for rater A (Figure 3a) shows his evaluation of the projects along the x axis. This means that whilst he rates the chosen projects highly, he also gave high marks to those at the top right. The projects in the lowest ranks are positioned on the right of the plot, both top and bottom.

Examination of the item plots therefore gives an indication of the differences in the raters' evaluations of the projects, shows which of the raters are in agreement, and therefore reveals possible allies in the decision making group. Specifically, this type of analysis provides a detailed picture of which proposals cause agreement and disagreement amongst the raters, and the extent to which the raters' personal views have been accounted for in the decision.

1.3 The Individual Ratings ([ExA] for P(raters))

1.3.1 Introduction

The first section has shown the use of POSA for analysing the rank orders created by all of the raters. In that case the quantitative dimension was the value of the proposals in terms of their ranks. The qualitative differences were the different raters' opinions of the rank order of the proposals. However, by using the rank orders, which were created by adding the scores on the ten qualitatively different criteria, a lot of information about the basis of these decisions is lost.

It is therefore possible to examine a number of ways in which this decision making exercise could be improved by POSA representation of the original data which was used to develop the rank orders. In considering the original data, quantitative variation is the sum of the scores across the original ten criteria or attributes, and the qualitative dimension is the different ways of obtaining that score in terms of different attributes.

Whilst the first example examined the differences between the individual raters in terms of their rank orders, the following section focuses in on the potential for POSA in structuring the individuals' viewpoints prior to the group discussion. Section 3 therefore examines the way in which POSA can be used to structure the individual raters' information prior to the development of rank orders. Rather than taking the current additive approach to assessment, POSA combines the quantitative dimension with representation of the qualitatively different strengths and weaknesses of the proposals. This would allow raters to use their own judgement of which criteria are of most value when selecting a proposal for funding.

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1.3.2 Construction of the Data Set

In creating the rank orders, each rater is asked to give a score to each project on each of ten criteria. At the University of Surrey an ad hoc procedure has been developed so that the possible maximum score is varied so that when the scores are added and converted into ranks there is a weighting involved which places more emphasis on certain criteria, for example more points can be awarded for innovation and novelty (maximum 20), than for industrial involvement (maximum 5). In order to demonstrate the qualitative differences between the proposals, each of the score ranges have been converted to form the same scale of quantitative variation, from 1 (the best scores on a particular range) to 5 (the worst scores). POSA can be used to show the differences and similarities between the proposals both quantitatively, and in terms of qualitative differences in their strengths and weaknesses.

The first application of POSA to the full data set represents each individual member's view of the proposals in a separate POSA, the matrix being of the type [ExA] with respect to Pn. The format of the matrix is thus;

```
For Person Pn              Attributes
                A1  A2  A3  A4  . . .  An

Entities        E1   1   2   2   1
(proposals)     E2   3   3   4   2
                E3
                E4
                .
                .
                En
```

In this example there are sixteen entities (proposals), ten attributes (criteria) and the cells represent the best (1) to the worst (5) scores on each criteria.

1.3.3 Results

i) Individual Judgement Style

The six POSA plots shown in figures 4 to 9 show the overall scaling of the proposals according to the six raters' views. It can be seen that in terms of the quantitative dimension, the further towards the bottom left hand side of the plot the more positive overall the rater judged the proposal. The circles on the plots show the projects which were eventually chosen, and therefore illustrate the extent to which the judgement reached by the committee was in accordance with individual raters' own evaluations of the projects before the meeting.

It is possible to examine the general differences in the way each rater assessed the proposals by looking at the different configurations of the POSA plot. The extent to which the proposals vary across the joint and lateral axes indicates the extent to which each rater perceived the proposals as quantitatively and qualitatively different respectively.

17
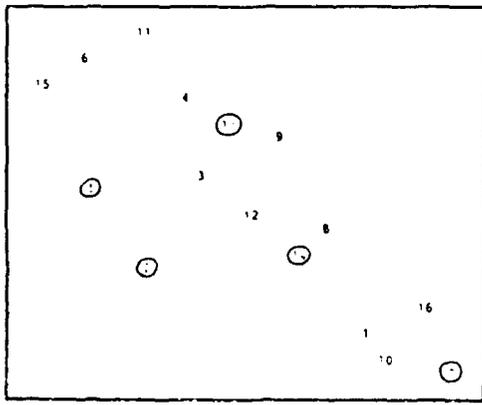
Figure 4. Rater A
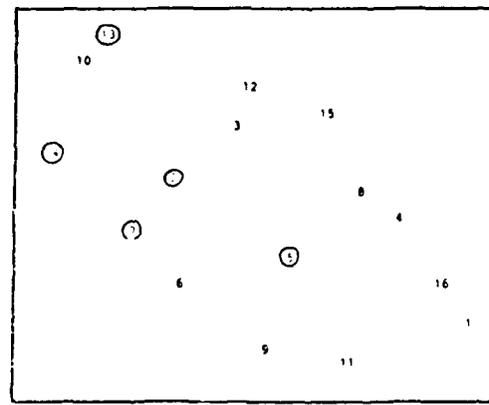
Figure 5. Rater B
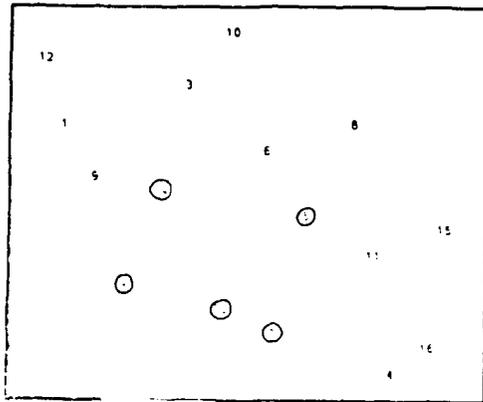
Figure 6. Rater C
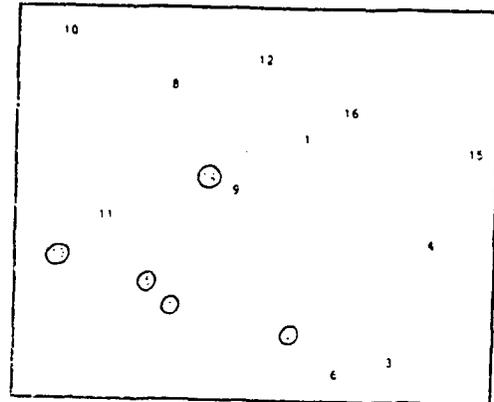
Figure 7. Rater D
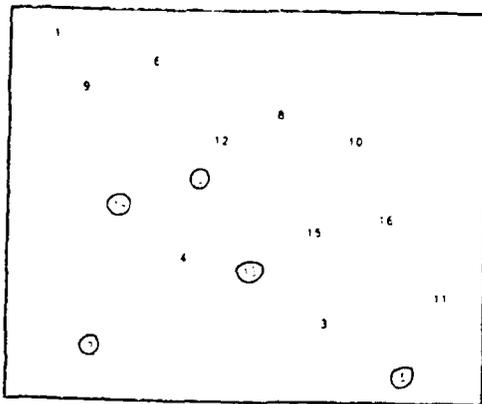
Figure 8. Rater E
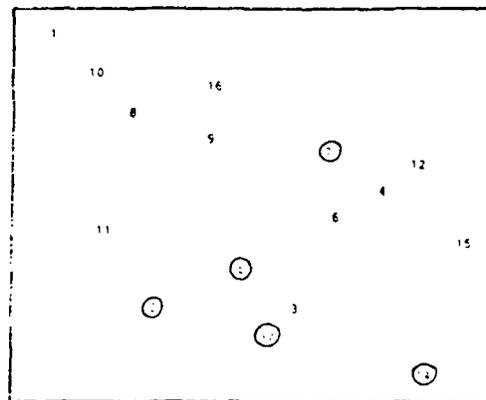
Figure 9. Rater F

Figures 4 to 9. Individual POSA Plots Showing Proposals Rated on Ten Attributes for Each of the Six Raters.

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This suggests that whilst the raters can convert their sum of scores into a rank order, there will be variation in the size of the differences between the proposals as perceived by each rater.

For example, the points representing the proposals for rater A (Figure 4) do not run across the full length of the x + y or joint axis. Therefore, whilst rater A was able to convert his scores into a rank order, the size of the differences between the projects in quantitative terms would have been smaller than those of rater D, for example.

This indicates that rater A did not make very strong differentiation between the proposals in terms of their total quantitative value, ie the projects all add up to similar worth when a quantitative analysis is taken. This is characteristic of a difficult decision. Whilst the other raters also show this type of configuration, the points are more spread
along the joint (x+y) axis showing more differentiation in terms of the quantitative dimension.

Figures 4 to 9, then, encapsulate the differences between each individual's initial conceptions and the eventual group decision. They show for instance that individual C, has the groups' choice clearly in the region of his own most preferred projects. Individual B by contrast, although also having the group's choice in the area of his preferred options, they are nonetheless skewed towards a particular qualitative sub-set. This is a different set of qualities to those of individual F as can be seen both from the region in which the group choices reside and from the projects that are in the remainder of the regions.

In order to understand further the way in which these plots may be used by the individual raters to structure their own thoughts on the proposals prior to the meeting and the advantages over the additive approach, it is necessary to consider the qualitative differences in more depth.

Two examples of POSA on the individual data are considered;

i)   Rater A, who appears to use the least quantitative differentiation between the proposals and

ii)   Rater D, who appears to use the most quantitative variation in his rating of the projects.

ii) Example One: Rater A

Figures 10a to 10j show the item plots of the POSA shown in Figure 4. These plots therefore show rater A's opinions of the sixteen projects rated on the ten different attributes. The item plots are partitioned so that regions are created to encompass all the proposals which rater one felt scored similarly (from best:1 to worst:5) on that criteria.

The first item plot (Figure 10a) shows the proposals divided according to rater A's perceptions of the differences in 'Innovation and Novelty'. The plot for this attribute partitions across the joint axis, showing that proposals five and two have high scores for novelty and innovation. The next partition shows those proposals which scored three, and the remainder scored four or five. This attribute therefore accounts for some of the quantitative difference between proposals five and two and the other proposals.

19
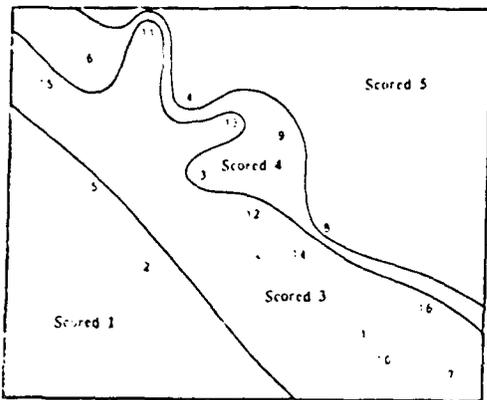
Figure 10a. Innovation and Novelty
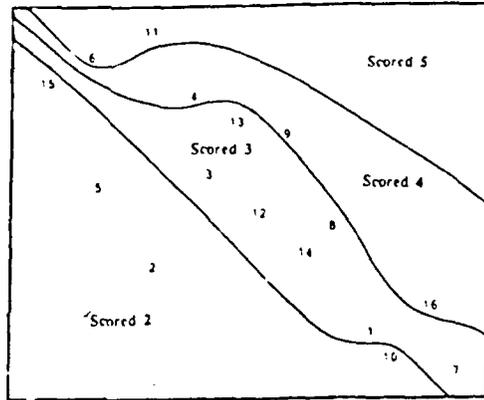
Figure 10b. Background Knowledge/Benefits
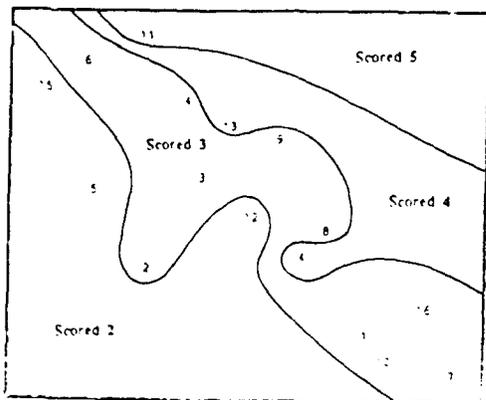
Figure 10c. Justification of Resources
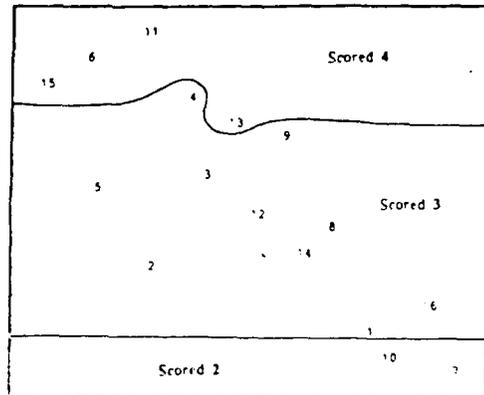
Figure 10d. Likelihood of Success
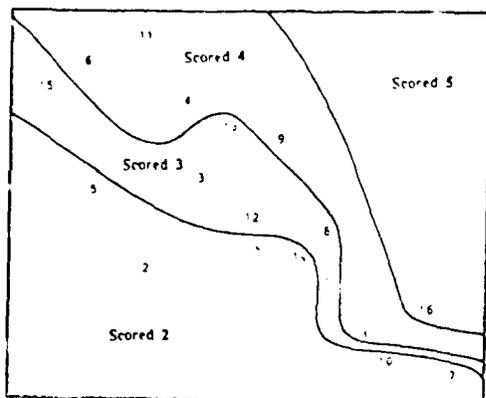
Figure 10e. Follow-up Money
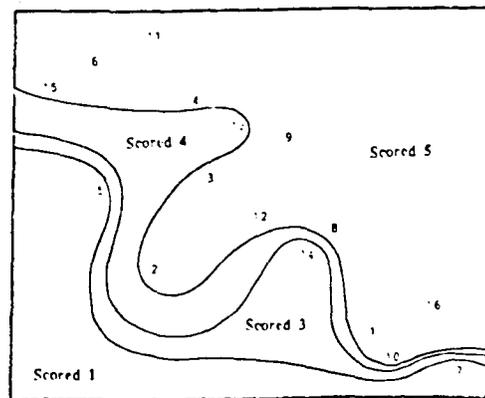
Figure 10f. Interdisciplinary

Figure 10a to 10f. Overall POSA Plot for Rater A, Partitioned According to Scores Given on Each Attribute.
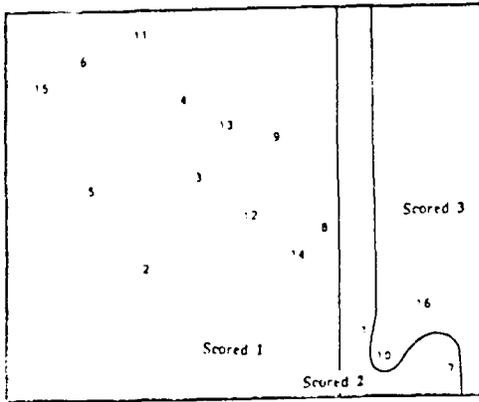
Figure 10g. Juniority
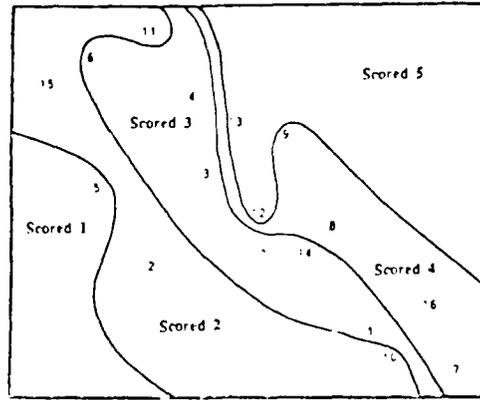
Figure 10h. Features in Departmental Plan
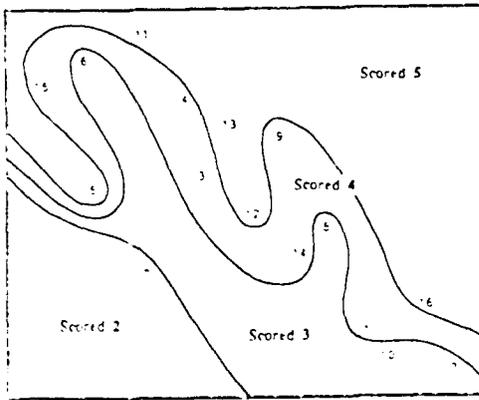
Figure 10i. Departmental Resource Backing
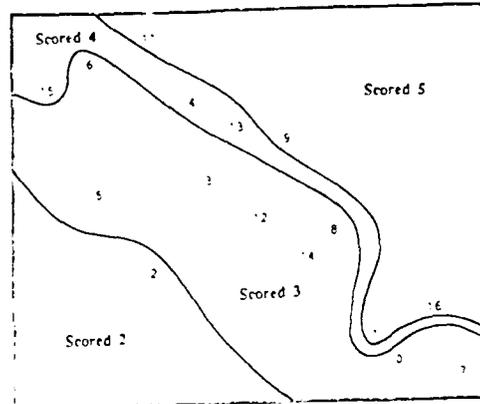
Figure 10j. Industrial Involvement

Figure 10g to 10j. Overall POSA Plot for Rater A, Partitioned According to Scores Given on Each Attribute.

Also partitioning across the joint axis is 'Background Knowledge/Benefits to Other Work' (Figure 10b). Here again projects two and five score '2' along with projects ten and fifteen. The remainder scored three, four, or five points from this rater. Similarly, most of the proposals do not score well in terms of their 'Departmental Resource Backing' (Figure 10i), or their 'Industrial Involvement' (figure 10j) , with only proposal two scoring well on these attributes.

The item plot referring to 'Justification of Resources' is shown in Figure 10c. Here most of the proposals score an average mark, three. Exceptions are proposals fifteen and five which score above average. For rater A, the worst justification of resources is proposal eleven scoring five, and proposals thirteen and fourteen (both of which were chosen by the group) with scores of four.

Also partitioning along the joint axis is the attribute which measures the likelihood of the project leading to follow up money from outside the University (Figure 10e). Rater A sees four of the five chosen proposals favourably in this respect. On the other hand although the item plot for 'Interdisciplinary' (Figure 10f) partitions on the joint axis, rater A makes very little distinction between the proposals on this dimension. The scores for 'interdisciplinary' are almost all fives, although the proposals scoring four (proposal 13), and three proposal 14) were chosen, along with the two which this rater felt to be truly interdisciplinary, proposals five and seven.

The extent to which the proposals are considered to 'Feature in the Departmental Plan' is shown in Figure 10h. Again proposal thirteen scores very badly, and proposals seven and fourteen score four and three respectively. However, proposals five and two score well on this attribute.

These eight attributes then, are all partitioned on the joint axis. Only two attributes distinguish between the proposals in a different way. The first of these is 'Juniority', (Figure 10g) which partitions the plot along the x axis. In this plot it can be seen that rater A believes that all but four of the projects (on the right hand side) are submitted by junior members of staff. This category covers all the chosen proposals but for proposal number seven which was thought to be submitted by a relatively senior member of staff.

Interestingly the other attribute which is not partitioned on the joint axis, partitions orthogonal to 'Juniority' along the y axis (Figure 10d). This indicates that there is no relationship between the seniority of the staff and the perceived likelihood of success of most of the projects. However, the two projects which score the highest in terms of probability of success are also two of the four thought to be submitted by more senior staff. With respect to those proposals which were chosen, only project seven scored a two from this rater.

Rater A could use these diagrams in order to make his choices for the rank order. Proposals five and two stand out as receiving higher scores on most of the attributes, and therefore would be predicted to be easy choices.

On the other hand, this rater would probably not be in favour of proposals thirteen and fourteen, scoring only averagely on 'Innovation; and Benefits', and scoring badly on 'Justification of Resources'. Proposal thirteen scores particularly badly on a number of

dimensions and would be predicted to be the choice with which this rater is the least satisfied.

The negative points of proposal seven are balanced by the fact that it has less chance of producing 'follow up money' and scores well on interdisciplinary, and probability of success.

Figure 11 shows the regions containing the best projects on each dimension shaded in to illustrate the overall opinions of this rater. From a diagram such as this it is possible to predict that proposals five and two would have been acceptable to this rater, and project seven have been another reasonable choice. However, provided the group discussion did not change his views he would have probably been more satisfied with choices of proposals ten and fifteen than project fourteen, and would be hypothesised to be particularly dissatisfied with the committee's choice of proposal thirteen.

The differences between the proposals discussed above is clear from simple analysis of quantitative differences between the proposals. However, it has been hypothesised that use of the item plots would be particularly important when considering which attributes or combinations of attributes the individual rater considered to be important in the decision.

The partitioning of the plots has shown that for this rater there is a strong relationship between the scores assigned to the proposals on eight of the ten attributes. Thus the better a proposal scores on one, the more likely it is to also score on seven others.

Thus rather than ten qualities, rater A's perceptions can be described in terms of three; probability of success, juniority, and a combined set of the other attributes which relate to the proposals in the same way. In addition these distinctions are made along the x+y or joint axis indicating that this rater is using a mainly quantitative assessment of the projects.

In a sense this would predict an easy decision for rater A, since he would not need to decide which of a set of conflicting qualities were the most important. On the other hand this rater attributes very little quantitative variation between the proposals, i.e whilst they are spread across the evaluative scale, from one to five, they are less likely to have 'extreme' scores of all good or all bad. This would make it particularly difficult for rater A to assess which of the proposals was the 'best' on this combined set of attributes.

iii) Example Two: Rater D

In contrast to rater A, the item plots illustrate a different picture of rater D's conceptions of the research projects. The POSA plots for rater A showed that eight of the attributes distinguished between the projects in the same way, along the 'joint' axis. The item plots for rater D's scoring of the proposals partition the plots in a number of different ways.

Unlike rater A, only two of the attributes partition the space along the joint axis, and these are 'Juniority' and 'Industrial Involvement' (Figures 12g and 12j). For 'juniority' rater D used the whole range of the scale to classify the relative seniority of the staff submitting the proposals. Of the proposals which were eventually chosen, three were considered to be submitted by the most junior staff. Although this rater does not consider any of the proposals to have particularly good or particularly bad industrial involvement, all five of the selected projects scored a two from this rater. On both of these attributes project eleven scores highly,

23
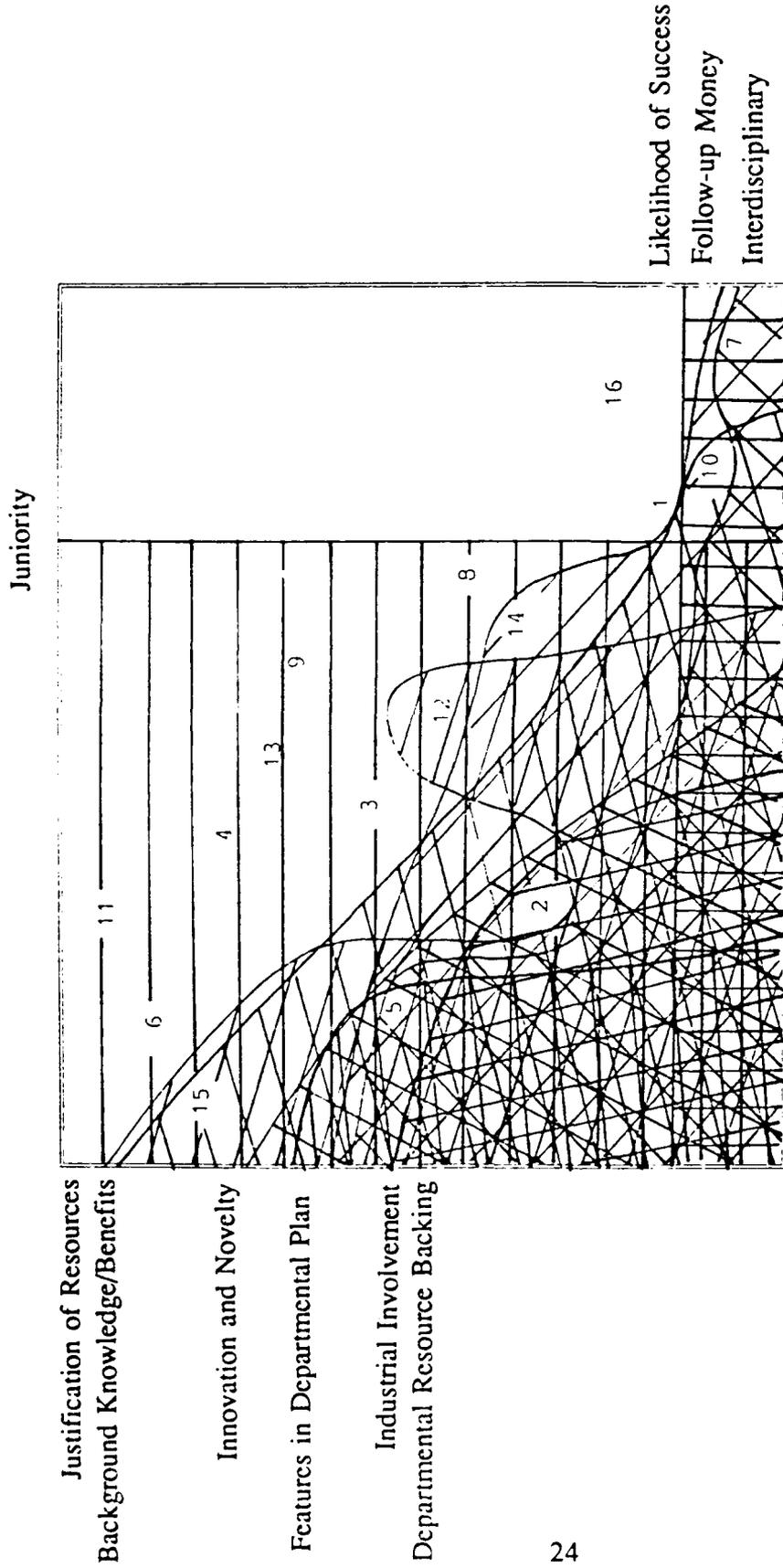
Figure 11. Overall POSA Plot for Rater A, Showing the Proposals which Score Most Highly on Each Attribute in Shaded Regions.

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although this was not one of the chosen proposals.

The previous section demonstrated that it was possible to combine eight attributes according to the way in which they were used by rater A. For rater D, four of the attributes relate to the proposals in the same way, i.e. partitioning the plots along the 'y' axis. These are the 'Benefits to Other Work' Figure 12b), 'Justification of Resources' (Figure 12c), 'Probability of Success (Figure 12d), and the extent to which the projects feature in the departmental plan (Figure 12h). Thus, the relationship between these four attributes indicates that those projects which are perceived as better on one attribute by rater D, are also perceived as being better on the others.

Figure 12b shows the item plot for 'Benefits to Other Work'. Most of the chosen proposals score the highest score this rater gives on this attribute. Similarly, Figure 12c shows the partitioning across the y axis for the 'Justification of Resources' and whilst proposals fourteen and five have average scores on this dimension, proposals thirteen seven and two have scored the maximum given by this rater. Figure 12d shows the item plot for 'Probability of Success'. Whilst all of the proposals have been given a score of two or three for their chances of success, three of the chosen proposals score two on this attribute. Finally, the partitioning for 'Features in the Departmental Plan' shows that the chosen proposals are again more likely to score the highest on this attribute (Figure 12h).

Therefore, if a project scores well according to its place in the department's plan, it will also tend to have good scores on 'Justification of Resources' and 'Probability of Success'. Similarly, if the project is thought to be of 'Benefit to Other Work' then it is also likely to have good justification of resources and high probability of success.

There are two possible explanations for the relationships between the attributes. Firstly, it is possible that the authors of the proposals who make a good argument to justify their resources and the probability of the success of their work, are also those which are good at arguing for the benefit of their work, and its position in relation to their department's plan.

However, a second possible explanation for this finding lies with the rater who perceives this relationship. That is that a rater who sees benefits for other work and a place in a departmental plan will also tend to give high marks for their resource justification and their probability of success. Examination of the way in which rater A evaluated the projects suggests that there are differences in the way each rater structures his or her evaluations. A more detailed examination of the way in which POSA can be used to reveal consistencies in the judgement style of the raters will be discussed in section 4.4.

Having considered the four attributes which are highly associated in the judgements of rater D, it is interesting to note that there is one attribute which is orthogonal to these four, ie it partitions the POSA plot across the x axis. This attribute is the interdisciplinary nature of the projects and is shown in Figure 12f. This attribute clearly distinguishes between the proposal along the x axis and thus bears no relationship to their benefits to other work, justification of resources, role in the department's plan, or indeed their probability of success. Of the selected proposals only proposal thirteen scores well for this attribute.

The structures of the remaining three attributes play a more complex role in the partitioning
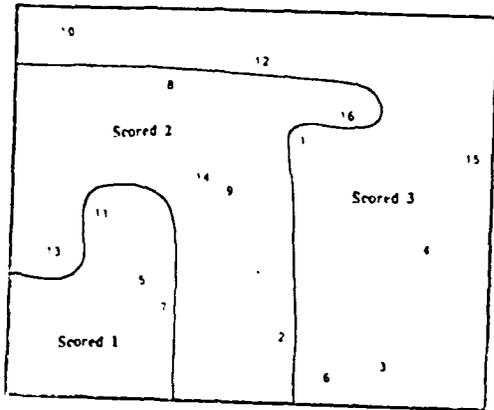
Figure 12a. Innovation and Novelty
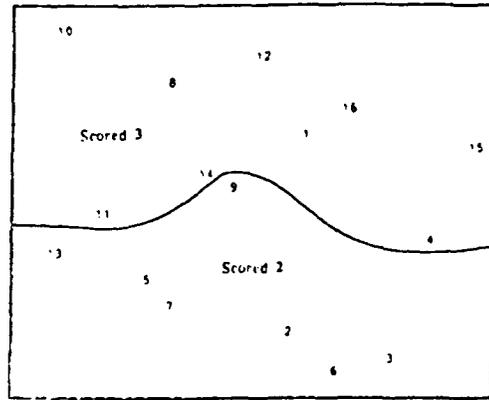
Figure 12b. Background Knowledge/Benefits
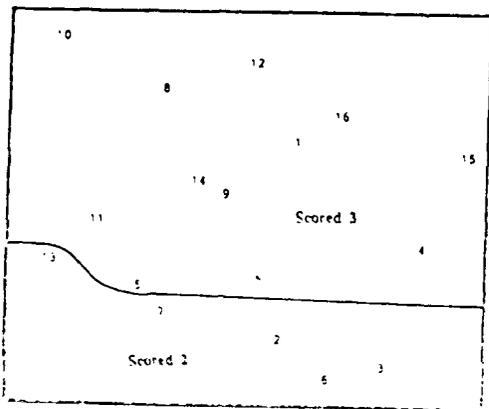
Figure 12c. Justification of Resources
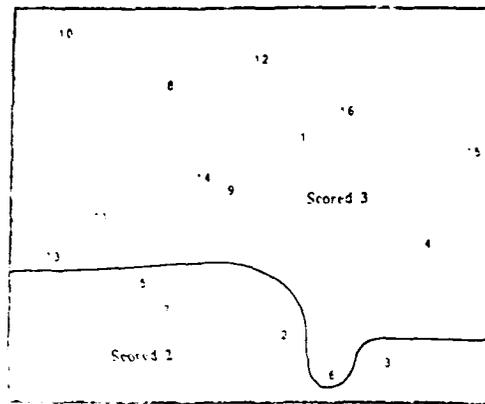
Figure 12d. Likelihood of Success
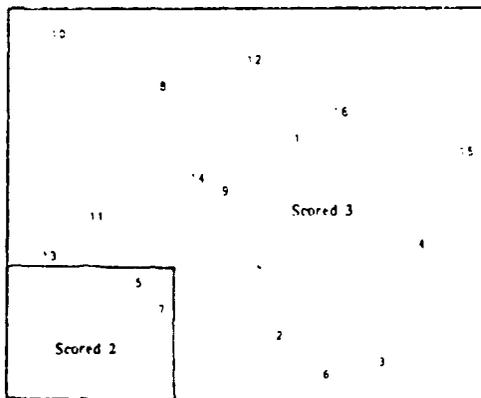
Figure 12e. Follow-up Money
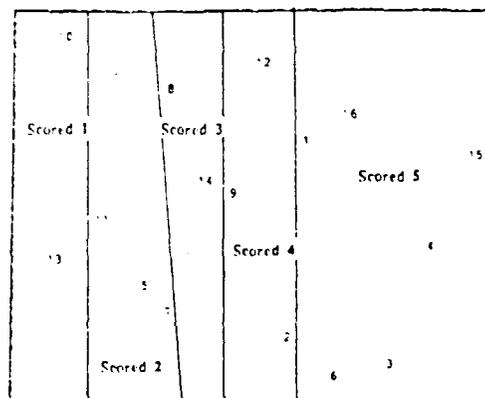
Figure 12f. Interdisciplinary

Figure 12a to 12f Overall POSA Plot for Rater D, Partitioned According to Scores Given on Each Attribute.

26
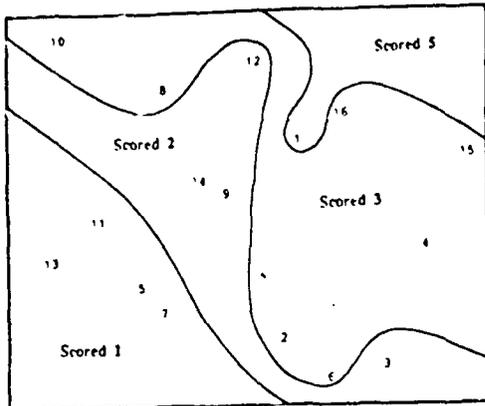
Figure 12g. Juniority
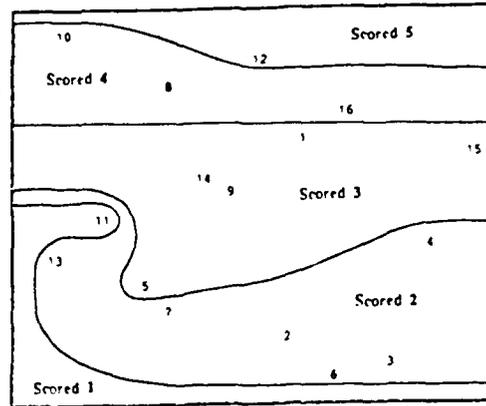
Figure 12h. Features in Departmental Plan
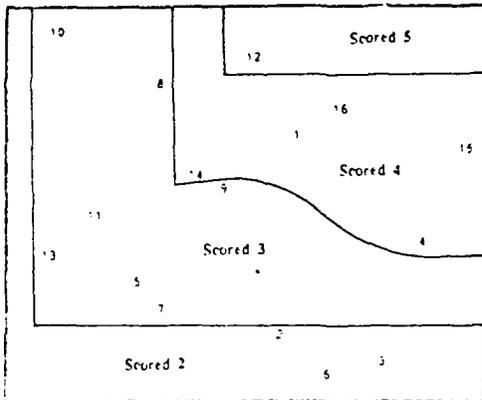
Figure 12i. Departmental Resource Backing
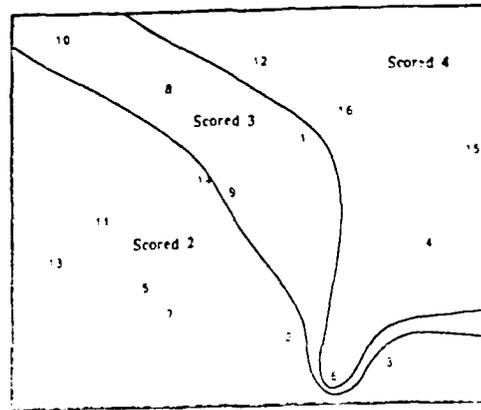
Figure 12j. Industrial Involvement

Figure 12g to 12j Overall POSA Plot for Rater D, Partitioned According to Scores
Given on Each Attribute.

of the space and are known as 'P' (Departmental Resource Backing: Figure 12i) and 'Q' ('Innovation and Novelty' and 'Follow-up Money': Figures 12a and 12e). In the case of 'Q, (see Figures 12a and 12e) this simply means that those proposals at the bottom right hand side of the plot received the highest scores. However, the remainder of the proposals do not score worse in a simple linear way, as with the partitioning along the joint axis. Instead the dimensions are 'bent' so that the worst proposals can be found at the outer edges of the plot, along both the x and the y axis. Partitioning 'P' is simply the reverse of this pattern, and is illustrated in Figure 12i.

These structures can be seen to relate to the combinations of the other attributes.
A proposal which is thought of as highly innovative (Figure 12a) is also likely to score well on 'Benefits to Other Work' (Figure 12b) and its interdisciplinary nature (Figure 12f). On the other hand, proposals which score well on 'benefits to other work' but not on interdisciplinary collaboration or well on interdisciplinary collaboration but badly on benefits to other work are both rated as poor in terms of innovation and novelty. Thus innovative proposals are likely to possess both of the other qualities.

Similarly, comparison of Figures 12i, 12f and 12b illustrate the structure 'P'. Those proposals that score better on departmental resource backing can score across the range in terms of both interdisciplinary nature and their benefits to other work. On the other hand, those that score badly on both these two dimensions are more likely to be those that score badly in terms of departmental backing.

The summary diagram for rater D is shown in figure 13, with the best categories on each of the ten attributes being shaded in. Proposals thirteen, five, seven and two fall into the most shaded regions for this rater, predicting that this rater would be reasonably happy with the final group decision. However, proposal fourteen only scores well on one of the criteria, its industrial involvement. It could therefore be hypothesised that unless his colleagues were able to convince him otherwise rater A would not be satisfied with the group's decision on this project, and that he would have preferred the choice of proposals six, three, or eleven.

However, such a conclusion is based on the assumption that high scores on more attributes makes a project more worthwhile. Unlike rater A, rater D sees the proposals as having qualitatively different strengths and weaknesses. Assessing the different criteria and combinations of criteria would allow rater D to consider which axes in the POSA plot represented the most important strengths of the proposals. Once that decision is made it would be easier for rater D to select his preferred proposals than rater A, since they are more clearly distinguished from one another according to their value on each attribute.
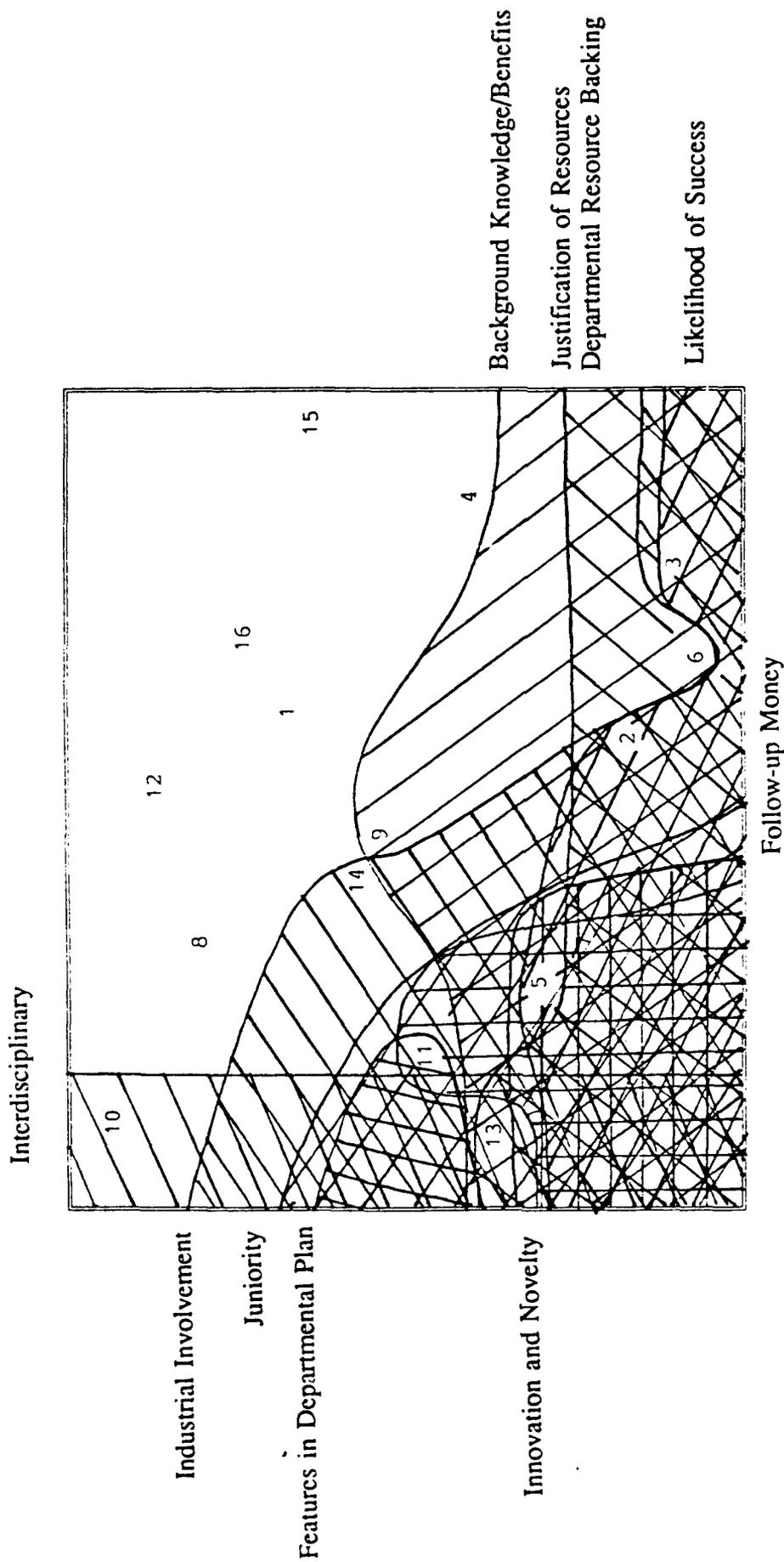
Figure 13. Overall POSA Plot for Rater D, Showing the Proposals which Score Most Highly on Each Attribute in Shaded Regions.

1.4. All Raters' Judgements on all Attributes ([EPxA])

1.4.1 Introduction

If each rater's view of each of the projects on all of the variables is analysed using POSA, then each point plotted in the space represents a person's view of a project. In this way it is possible to examine two factors in the raters' perceptions of the projects.

    i)   Firstly it is possible to compare each rater's view of all the projects, ie the rater's 'judgement style', whether they tend to judge all the projects in a similar way.

    ii)   Secondly, it is possible to examine the agreement between the six raters with respect to each of the individual projects, ie the extent to which each of the raters agree with one another regarding a particular project.

1.4.2 Construction of the Data Set

The final examples take the most complex matrix where entities (the proposals) as classified by the people (raters) are represented according to the original ten attributes. This matrix is thus [EPxA]. In this way POSA can be used not only to identify which of the decision makers agree and disagree, but on which attributes their disputes occur. This then is the fullest use of the data for POSA, maintaining all the data on the raters (P), proposals (E), and the criteria (A). The format of the matrix is therefore;

```
For Pn                    Attributes
                     A1   A2   A3   A4    .   .   .  An
People x
Entities        P1:E1  1    2    2    1
(proposals)     P1:E2  3    3    4    2
                P1:E3
                  .
                P1:En                         -
                P2:E1
                P2:E2
                P2:E3
                  .
                P2:En
                  .
                Pn:En
```

1.4.3 Interpretation of the POSA Plots

Analysis of the full matrix represented above produced the POSA plot shown in Figure 14. Each of the ten item plots are shown in Figure 14a to 14j.

It is first necessary to examine the way in which each of the attributes partition the POSA plot in order to interpret the evaluative structures being used by the raters.
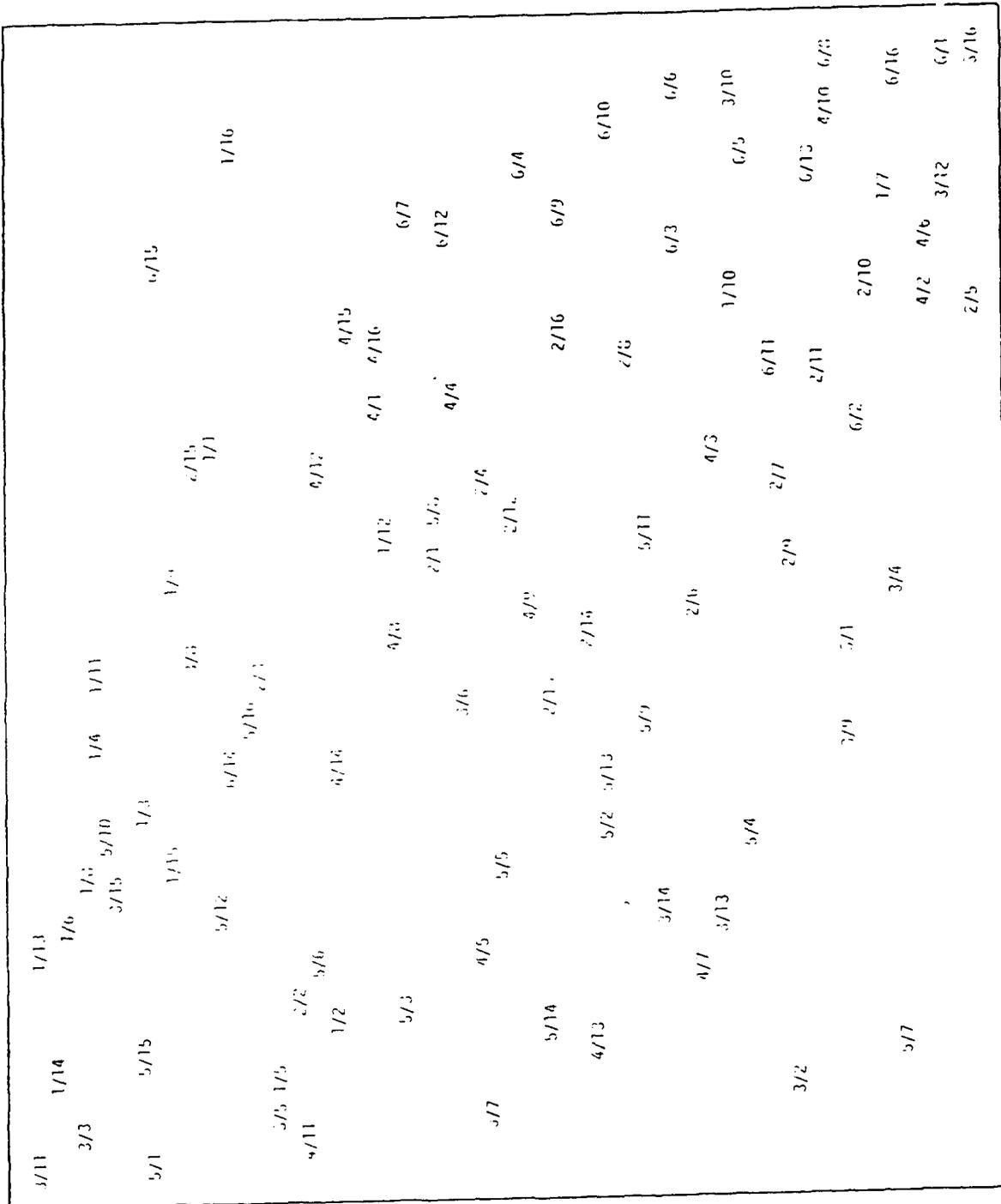
Figure 14. Overall Plot of All Six Individuals' Views of Sixteen Proposals Rated on Ten Attributes.

Three of the attributes partition the space along the y axis, and are related to one another in terms of the raters' evaluation schemes. These attributes, 'Benefits to Other Work', 'Justification of Resources' and 'Probability of Success' are shown in figures 14a, 14b and 14c. On these three variables, the further toward the bottom of the plot, the more likely the proposals are to have been judged positively.

The only attribute to partition the space along the x axis is 'Juniority' (Figure 14d), indicating that the further toward the left hand side of the plot, the more junior are the members of staff who are proposing the research. The fact that this attribute partitions the space orthogonally to the three attributes discussed above is interesting, as it indicates that their is no relationship between these variables. Projects submitted by junior or more senior staff are judged to have the same range of benefits and probability of success. The lack of relationship between 'Juniority' and the other variables, along with the fact that certain raters do not distinguish between proposals according to the attribute, (eg all full marks) suggests that it has little value as part of the decision criteria.

This type of analysis can therefore assess the relationship between the attributes as well as between the entities. Such relationships based on empirical data provide a rationale for structuring procedural aspects of the decision making process itself.

The remaining attributes all partition the POSA plot along the joint, or x+y axis, so that the further toward the bottom left hand corner of the plot the more likely the projects are to be thought of as innovative (Figure 14e), interdisciplinary (Figure 14f), to have resource backing (Figure 14g), to feature in their department's plan (Figure 14h), to produce follow up money (Figure 14i), and to have industrial involvement or interest (Figure 14j).

These ten attributes and the role they play in interpreting the POSA plot are summarised in Figure 15. It is now possible to examine in more detail the evaluations made by each of the raters in order to draw conclusions about their individual and comparative judgements of the proposals.

1.5 Analysis of the Raters' Judgement Style

By labelling the POSA so that each rater's view of all the projects are marked onto the plot it is possible to examine whether there are systematic differences in the style of judgement employed by each of the raters. Figures 16 to 21 show the POSA plot for each of the six raters. For each rater the points representing their opinions of all the projects are circled.

i) Rater A

Figure 16 shows that relative to the other raters, rater A tends to rate all the projects similarly, the majority being in the upper left hand side of the POSA plot. Referring to the interpretation of the plot in terms of the attributes, this rater judges all the proposals as having been submitted by relatively junior members of staff, and having little merit in terms of their background or benefits to other areas. This rater also judges that most of the proposals stand relatively little chance of success. The exceptions to this are, projects one and sixteen which are located in the top right hand side, being thought of as being submitted by more senior staff and projects ten and seven which are thought of quite differently, being located on the

Figure 14b. Justification of Resources

Figure 14d. Juniority
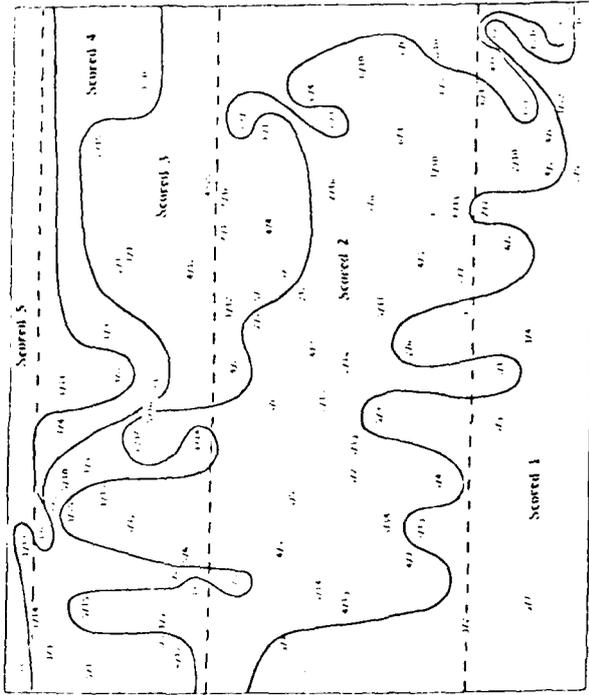
Figure 14a. Background Knowledge/Benefits
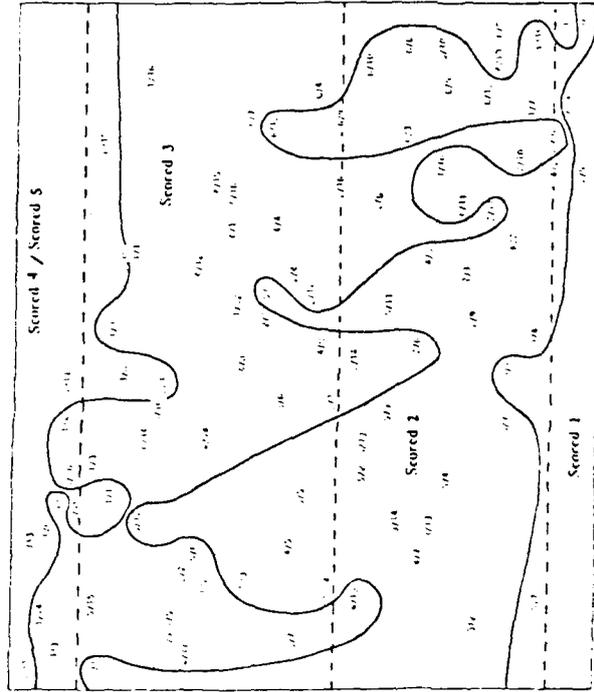
Figure 14c. Probability of Success

Figures 14a to 14d. Overall POSA Plot of All Raters Views of All Proposals Partitioned
According to Each Attribute

33
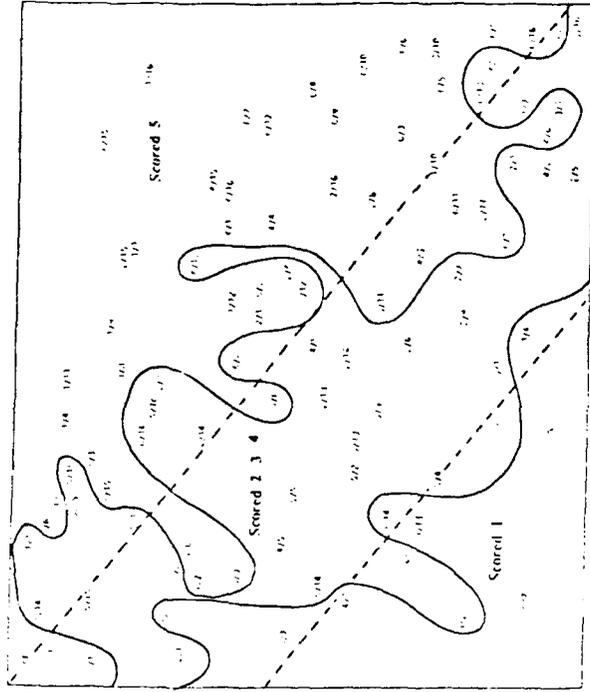
Figure 14f. Interdisciplinary

Figure 14h. Features in Departmental Plan

Figure 14e. Innovation and Novelty

Figure 14g. Departmental Resource Backing

Figures 14e to 14h. Overall POSA Plot of All Raters Views of All Proposals Partitioned According to Each Attribute.

34
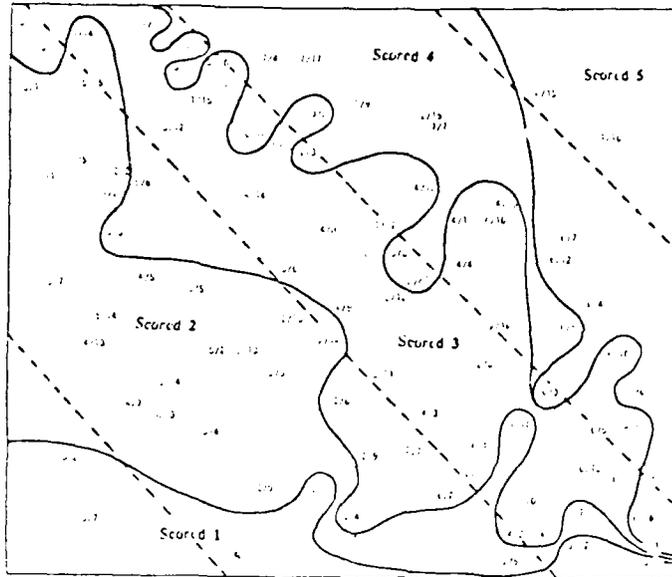
Figure 14i. Follow-up Money
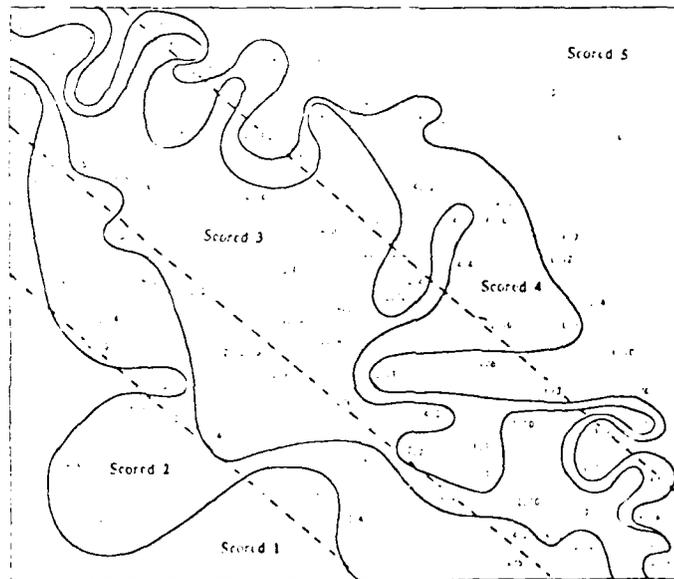
Figure 14j. Industrial Involvement

Figures 14i and 14j. Overall POSA Plot of All Raters Views of All Proposals Partitioned According to Each Attribute.

Background Knowledge/Bene
Probability of Success
Justification of Resources

Juniority

Innovation and Novelty
Departmental Resource Backing
Industrial Involvement
Features in Departmental Plan
Interdisciplinary
Follow-up Money
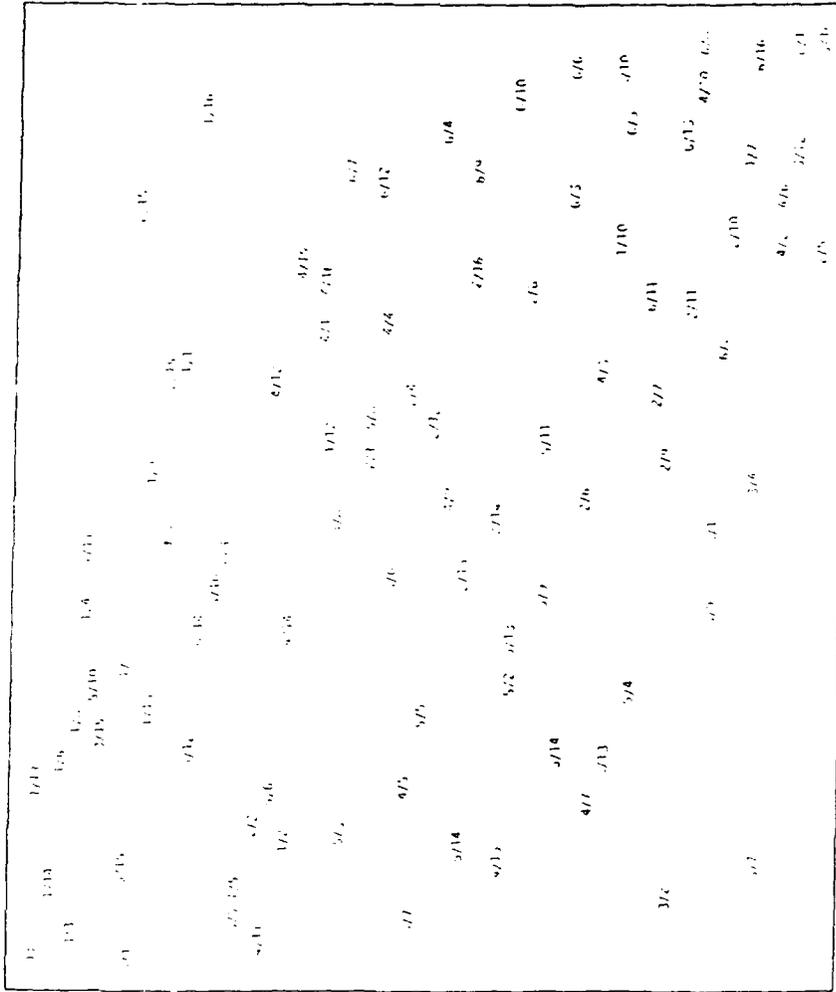
Figure 15. Summary Interpretation of POSA Plot Showing the Direction of Partitioning for Ten Attributes.
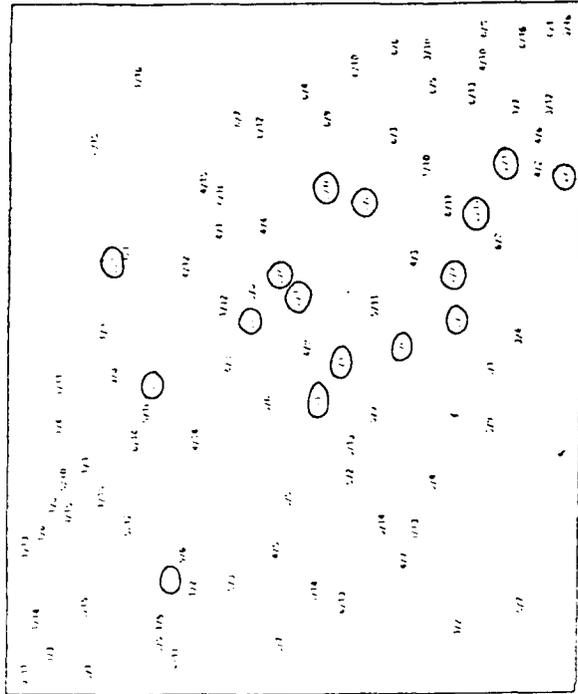
Figure 17. Rater B.
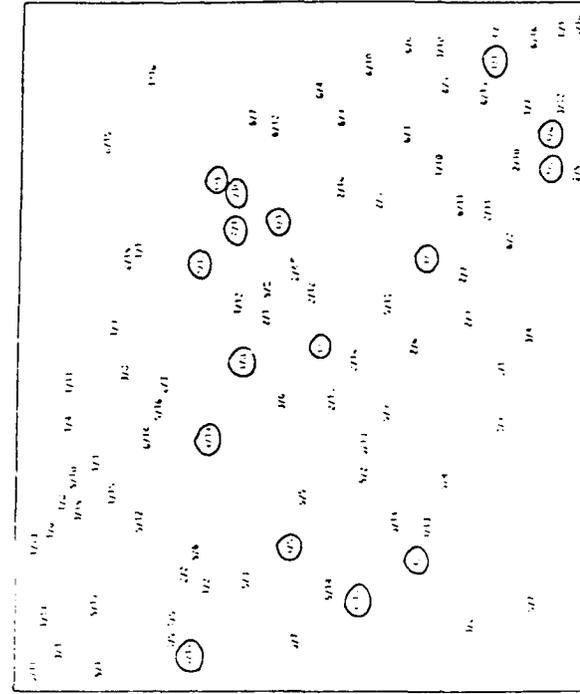
Figure 19. Rater D.

Figure 16. Rater A.

Figure 18. Rater C.

Figure 16 to 19. Overall POSA Plot of All Raters Views of All Proposals. The Points Referring to Each Individual Rater's Views are Circled.

37
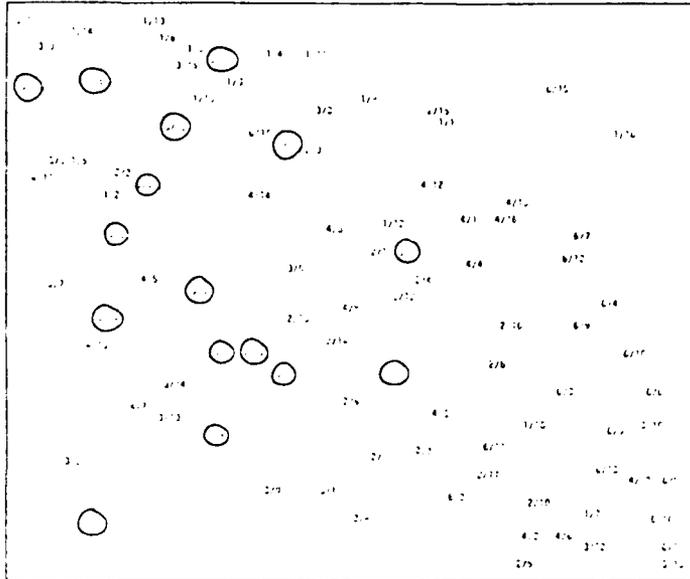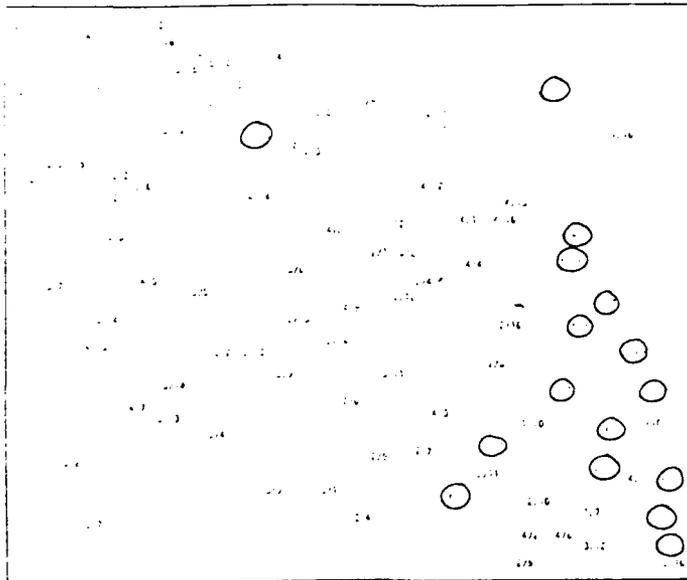
Figure 20. Rater E.

Figure 21. Rater F.

Figure 20 and 21. Overall POSA Plot of All Raters Views of All Proposals. The Points Referring to Each Individual Rater's Views are Circled.

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bottom right hand side. These projects, thought to be submitted by more senior staff members, are considered to have better justification of resources, more benefits to other work and more likelihood of success.

ii) Rater B

The points which refer to rater B's opinions of the projects are shown in figure 17, and are found towards the bottom centre/right hand side of the plot. This suggests that rater B makes few distinctions between the juniority of the staff submissions, rating them all as quite senior. This rater also makes few distinctions between the projects in terms of the attributes associated with the joint axis. However, the proposals do vary along the y axis, i.e in terms of the background information and benefits of the proposals, their justification of resources and their probability of success. Rater B's opinions of proposals two, three and fifteen are somewhat different to the other proposals. These points are located further up the plot, suggesting less benefits to other work, less likelihood of success and poor justification of resources. Project two is also distinguished by being thought of as submitted by relatively junior members of staff.

iii) Rater C

Rater C appears to be using a wider system of judgement for the projects. The points referring to his views are well distributed across the plot, (see figure 16). This rater's views encompass the most extreme differences on the x and y axes. It also shows large qualitative differences. For example the 'corner points', sixteen (bottom right) and eleven (top left). Whilst proposal sixteen scores very well on benefits to other work, justification of resources and probability of success, it loses marks having been submitted by a more senior member of staff. On the other hand, proposal eleven is submitted by the most junior staff, but scores particularly badly on the 'y axis' attributes. In this case the decision maker would need to establish the extent to which positive discrimination should operate towards more junior staff.

Whilst many of the differences perceived by this rater can be accounted for by distinctions on the four attributes discussed above, he does also make some distinctions along the joint axis. His view of projects two, seven, thirteen and fourteen (all chosen) for example, are more positive on the 'joint' attributes.

iv) Rater D

Like rater C, rater D's opinions of the proposals are also more differentiated than those of raters A and B. (see Figure 19). For example, projects two, six and ten, (bottom right) are judged in a similar way to projects five, fourteen, and eleven (top left) on the joint axis, i.e in terms of their innovation, interdisciplinary nature, resource backing, industrial involvement, liklihood of generating more money and part played in the departmental plan. However, these projects are clearly thought to be quite different in terms of the attributes partitioning the POSA on the x and y axes. Thus, whilst projects two, six and ten were rated more positively in terms of their probability of success, benefits to other work and justification of resources, they were judged as being submitted by more senior members of staff. Conversely, projects eleven and fourteen although submitted by more junior members of staff fall short on these three important criteria.

v) Rater E

Figure 20 shows that rater E makes some distinctions between the projects in terms of the 'joint' attributes. For example, projects seven and four are rated highly on these attributes, and projects eight, ten, and sixteen are considered to be worse on these attributes.

However, the majority of the differences in this rater's opinions of the proposals are accounted for by the variables on the y axis, the proposals receiving a range of scores according to their benefits to other work, justification of resources, and probability of success. However, this variation is confined to the left hand side of the plot, indicating that the projects have not been differentiated in terms of juniority, all the projects being considered to have been submitted by junior members of staff.

vi) Rater F.

The proximity of the points shown in Figure 21 indicates that rater F has a very obvious style of judgement. He makes the least differentiated judgements of the proposals. The close configuration of points, shown mainly at the bottom right hand side of the POSA plot, indicates that there is a strong similarity in the way this rater evaluates the proposals. With the exception of project fourteen, rater six sees all the projects as submitted by relatively senior staff, and most as being of similar value in terms of the six attributes partitioning the joint axis. He does however, make distinctions amongst the proposals according to the three attributes partitioning the y axis, ie benefits to other work, justification of resources, and probability of success. Most of the projects score quite well on these criteria apart from projects fourteen and fifteen which are found towards the top of the plot.

Summary

Analysis of the POSA plots in terms of the individual raters' vie·)ints has demonstrated that there are strong individual differences between the raters in ι.rms of their evaluative schema. Indeed, the plots show much more clear demarcations between raters than between the criteria used to make the ratings indicating that the criteria are of relatively little significance.

Whilst some raters can be seen to be using all the criteria to distinguish between the projects, others make more limited distinctions, perceiving differences between the projects only on certain attributes.

Examination of the each rater's opinions of the five selected projects gives an overall picture of the extent to which they approved of the selected projects prior to the group discussion. The five projects selected are marked onto the plot in figure 22 for each of the six raters.

It can be seen that the majority of the proposals chosen are in the lower left hand side of the plot. However, the emphasis on the right hand side of the plot rather than the bottom tends to suggest that although 'juniority' was not well used by the raters it has had rather more impact on the decision than one might imagine. There are a number of proposals which were selected from the bottom right of the plot, being likely to succeed, of benefit to other work and when justified resources, yet being submitted by more senior staff. However, more

40
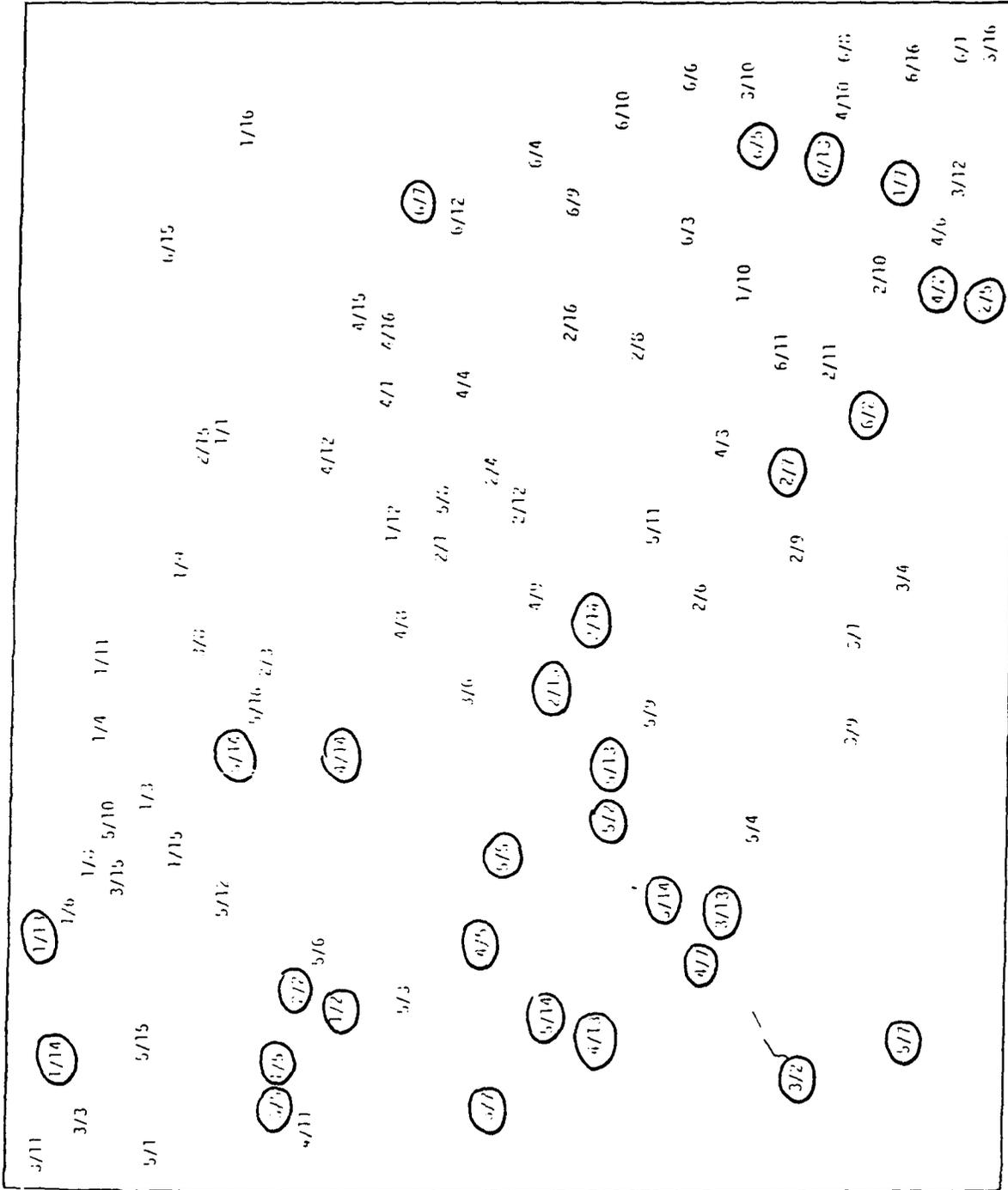
Figure 22. Overall POSA Plot of All Raters Views of All Proposals. Proposals Eventually Selected by the Group are Circled.

proposals are selected from the more junior authors even though they have lower scores on the other three variables.

If the group were to use such a representation in their decision making they would need to consider the qualitatively different criteria and decide which combinations of attributes would be the most beneficial. For example, they may decide that all the attributes are important and therefore select projects which are positioned in the bottom left hand side of the plot. On the other hand they may consider that juniority, for example, is less important than probability of success and the benefits to other work and therefore their selection can be focused more toward the bottom of the plot, regardless of the variation along the x axis. Interestingly, subsequent committees have taken 'juniority' as an essential criterion for admissability of projects to the competition. Now, only newly appointed members of staff may apply.

In terms of the raters' satisfaction with their representation in the decision, the POSA plot suggests that on the basis of his initial views, rater F would be less satisfied with the decision, his most favoured proposals being in the bottom right hand corner. In addition two of the proposals which were chosen (seven and fourteen) scored badly on the only attributes he did use.

1.6 Agreements and Disagreements Between the Raters

The same POSA plot can be used to compare the different rater's opinions of a particular project, and can therefore indicate the agreement between the group members regarding the proposals which have been submitted.

For example, circling the raters' views of the proposals onto the POSA plot it is possible to examine their distinctions between the projects within each discipline. Thus, if the academic background of the rater is known, the distinctions he makes between the projects in his own discipline can be compared to those made regarding projects with which he is less familiar. It is possible that raters are more able to distinguish the likelihood of success, for example, of projects based within areas with which they are familiar. If it is possible to display such a relationship between the background of the raters and their views on the projects then this holds implications regarding the nature of the decision making task.

In the following section the raters' opinions of the projects within two fields are marked onto the plot in order to compare directly the different raters' opinions of the projects. Since the relationship between the attributes has already been used to interpret of the POSA plots in section 4.3, it is also possible to examine the reasons why raters agree and disagree about the proposals.

1.6.1 Example One: Psychology

Two proposals were submitted from the psychology department and so it is possible to compare all the raters' views on both of these projects. Figure 23 shows the same overall POSA plot with the two psychology projects marked with respect to the six different raters. Project twelve is marked with a square and project fifteen with a circle.
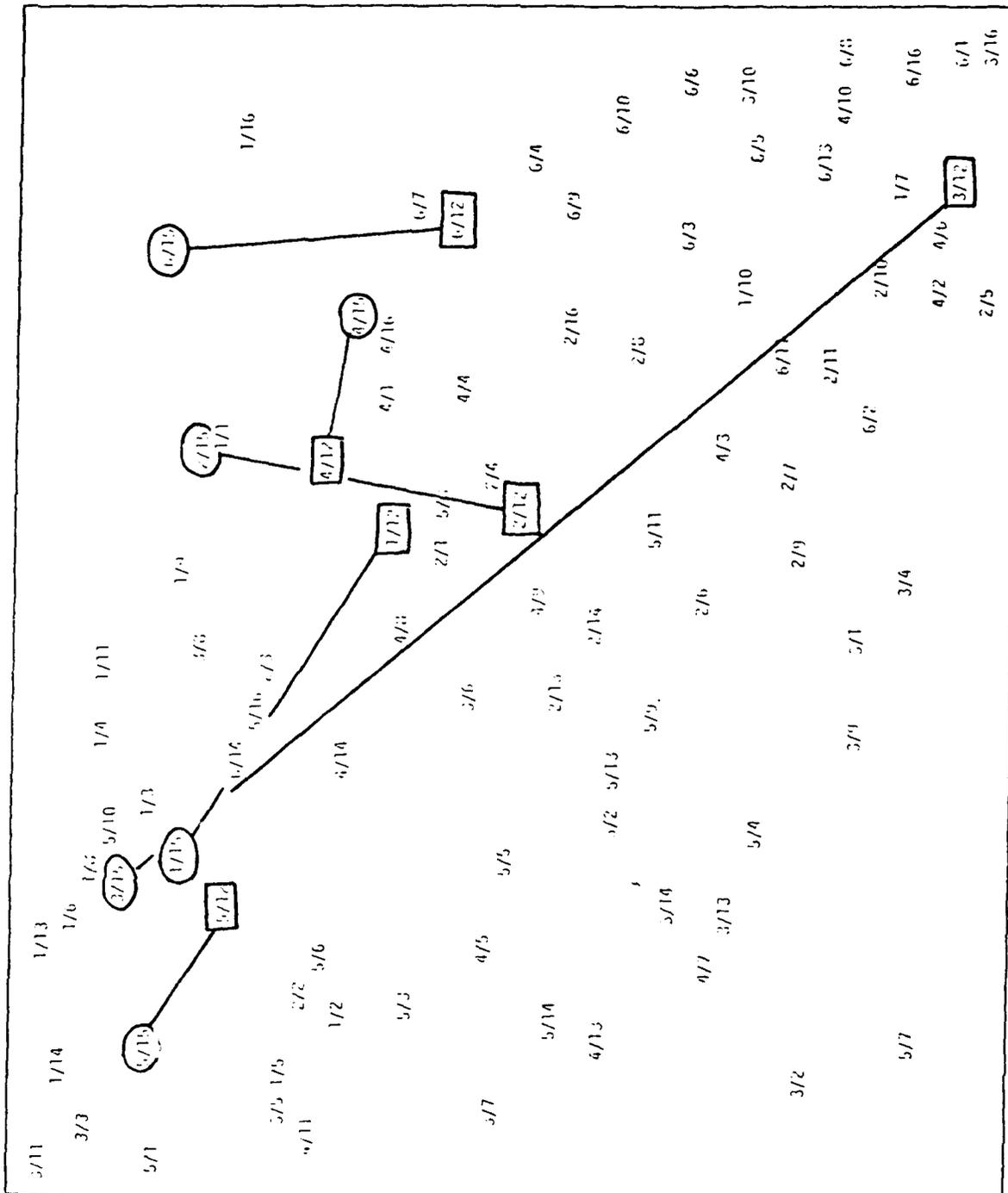
Figure 23. Overall POSA Plot of All Raters Views of All Proposals. The Points Referring to the Individual Rater's Views of Projects 12 and 15 are Marked.

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Agreement Between the Raters

Consideration of each project individually shows the extent to which the raters agree about the projects. Raters A, B, D and F have very similar opinions of proposal twelve. The points which refer to these four raters' views of this proposal are found in the upper right hand side of the plot, indicating that it is thought to be rather poor on all the attributes.

The point referring to rater E's view of project twelve is found at the upper left hand side of the plot, suggesting that he has possibly been slightly less harsh in his scores for innovation, interdisciplinary, features in departmental plan, resource backing, industrial involvement, and need for further money. However, the real difference between rater E and the other four raters lies in his judgement that its author is a more junior member of staff.

The only real disagreement between the raters therefore comes from rater C. The point representing rater C's view of project twelve is found in the bottom right hand side of the plot. This indicates that whilst he does not feel that the author is a junior member of staff, he does believe that the justification of resources, benefits of other work and probability of success are high.

Project fifteen is rated in the same way as project twelve by raters B, D and F. Its position in the POSA plot at the upper right hand corner indicates they have a poor opinion on all dimensions from these raters. However, Rater A, who agreed with the other three with respect to project twelve rates project fifteen as having been submitted by a more junior member of staff. Nevertheless, although raters A, C and E are slightly less harsh on this proposal in terms of the 'joint' attributes, project fifteen is located towards the very top of the plot for all six raters. This shows that they all agreed that this project had perhaps one of the worst chances of success, the least benefits to other work, and poor justification of resources.

In general terms the POSA shows that the raters are in quite high agreement regarding the poor quality of the two projects submitted from psychology. The only exception to this is rater C's much higher opinion of project twelve.

Academic Background

Finally, it is of some interest to compare the distinction each rater makes between the two projects. If for each rater the two project judgements are joined with a line, the distance between can be taken to represent the perceived difference between them. It is therefore interesting, to note that although most of the raters see only a small difference between the two projects, rater C's judgements are quite different. It may be that rater C simply has an interest in this particular project. On the other hand, it could be hypothesised that since rater C is a social scientist, his background enables him to make a better distinction between the chances of success and implications of this project than his pure science colleagues (raters D, E and F).

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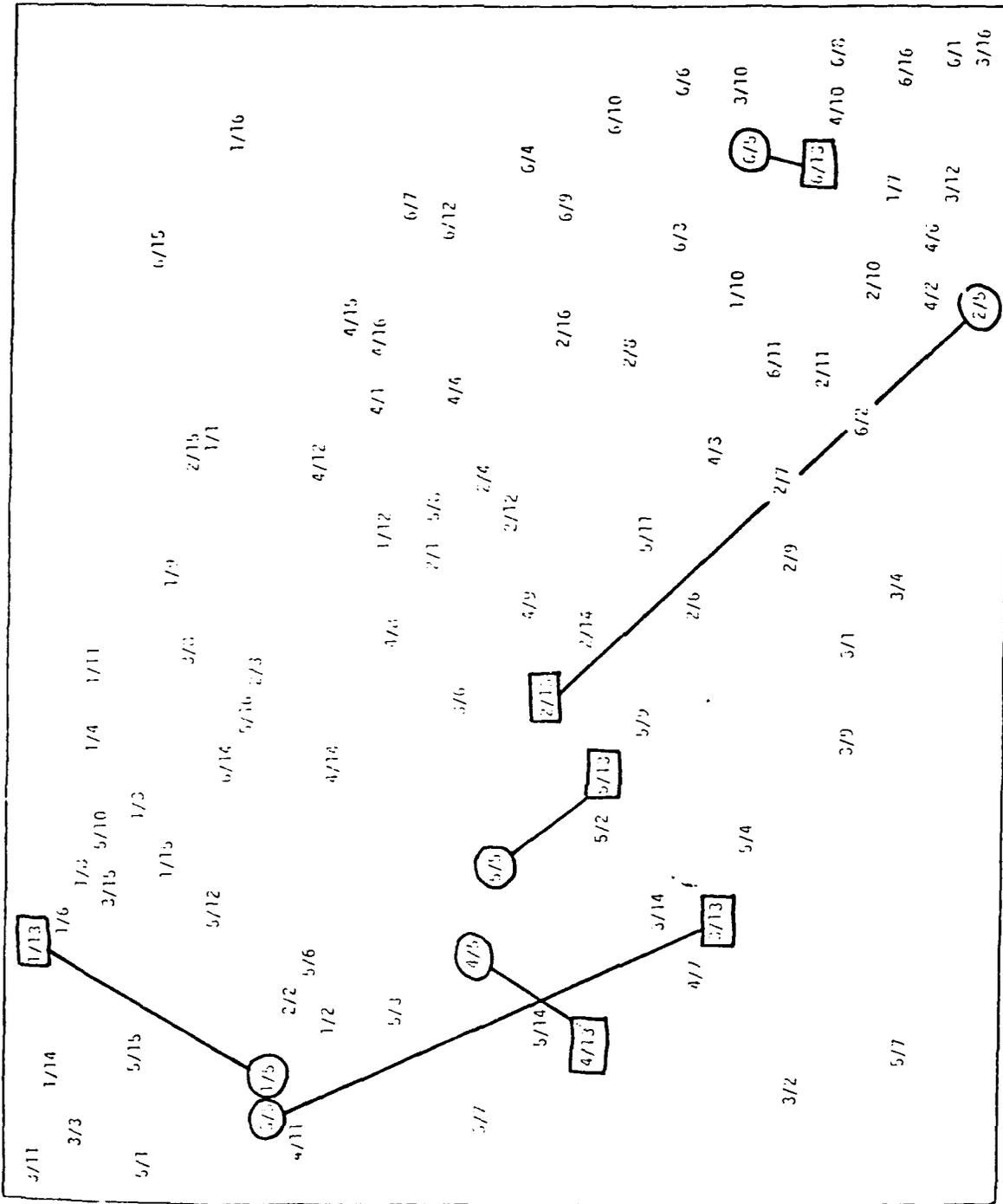
Figure 24. Overall POSA Plot of All Raters Views of All Proposals. The Points Referring to the Individual Rater's Views of Projects 5 and 13 are Marked.

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1.6.2 Example Two: Chemistry.

Figure 24 shows the same plot, again labelled with individual projects, in this instance two of the four proposals submitted from Chemistry. These proposals are particularly interesting since these two projects (five and thirteen) were eventually selected by the group.

Examination of the points referring to proposal five (circled) shows that all six raters' views of the project can be characterised by roughly the same judgement on the joint axis. That is they all think it to be of similar value with regard to innovation, its interdisciplinary nature, its resource backing, its role in the departmental plan, the industrial involvement, and the possible generation of follow up money.

However, when the other attributes are considered it can be seen that there are essentially three different opinions amongst the raters. Raters B and F feel that proposal five is submitted by senior members of staff, has high chance of success, good benefits for other work and has a well justified request for resources. Conversely, raters A and C give project five poor scores on these attributes, but believe it to be submitted by a junior member of staff. Raters D and E agree with one another that the author of proposal five is a junior member of staff and that the project has average benefits to other work, chances of success and justification of resources. It could be hypothesised that on this basis raters B and F would be happy with this particular decision, and raters A and C rather less so, depending on the emphasis placed on juniority.

Given that 'juniority' has a lower weighting in the additive approach it would not be surprising if this dimension was not considered in the decision. However in the light of the decision, it seems that with respect to the y axis attributes raters B and F had the more powerful argument. It would be of considerable interest to assess a decision like this with more detail of the actual discussion involved. POSA of the rank orders modelled the actual decision made, and the more detailed analysis holds testable predictions for people's contribution to the decision and their satisfaction with the choices made by the group.

One of the other proposals which was submitted from chemistry, and eventually selected, was proposal thirteen. With respect to this proposal it is raters B, C, D and E who are in agreement. All the points referring to these raters' views of this project are towards the bottom left hand side of the plot, indicating that they felt it to be of good quality on all of the attributes considered. However, the other two raters completely disagree, not only with the majority but also with each other. The point referring to rater A's view of the project can be found at the top right hand side of the plot, indicating that whilst he thought that the author was a junior member of staff he thought the project stood little chance of success, had few benefits to other work and did not justify its resources. Rater F, on the other hand thought quite the reverse, the position for his view of project thirteen indicating that he perceived the project not only to have been submitted by a senior member of staff but also that, like project five, it was of particular value on these three variables.

When the two chemistry projects are joined on the plot for each rater it is possible to look at the breadth of the raters' distinctions between the projects. Little distinction between the two projects was made by raters D, E and F.

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On the other hand, raters B and C made quite large distinctions between the projects, mainly in terms of their justification of resources, benefits to other work and probability of success. It is the judgements made by the raters must be viewed in the context of their opinions of the projects in general. For example, although rater F saw proposals five and thirteen as submitted by senior members of staff, he also rated the rest of the proposals in that way. Similarly, the findings for the chemistry proposals suggest that it is rater C's style, rather than his knowledge, (as suggested above) which leads him to use a broader scale of judgement with respect to the projects.

1.7 Summary and Conclusions

The range of POSA representations of this data have shown:

1. That it is possible to model the existing decision making process of the group in terms of the rank order data, whereby the proposals which were eventually chosen can be represented as the 'best' possible combination of the group's views.

2. The use of POSA has demonstrated that it is possible to examine the relationship between the criteria being used by the group in their assessment of the proposals. In particular it has shown that the raters do not use 'juniority' in conjunction with any other attribute.

3. The POSA analysis of the individual viewpoints of the raters prior to the decision making group has shown the potential for its use to structure individual viewpoints prior to the meeting. Such an analysis reveals to the rater which criteria they are using in conjunction with others, and the proposals which possess the various combinations of qualities which they may wish to consider during the group meeting.

4. The overall POSA plot using the full data has allowed the analysis of the raters' styles of judgement in comparison to one another and identified possible problem areas with the strategies. For example, whilst some of the raters are using all of the dimensions to distinguish between the projects others are not. Similarly, whilst several of the raters are not using the concept of juniority, some are applying seniority to all applicants and some are applying juniority to all applicants.

5. The overall POSA plot using the full data has allowed the comparison of all the raters views of individual projects. In this way it is possible to identify subgroups of opinion within the expert group and to allow disagreements between raters to be pinpointed with respect to exact attributes which cause these disagreements. This opens up the possibilities of modelling the cognitive basis of alliances and oppositions within decision making groups.

6. Finally, it has been possible to examine whether the raters are using similar types of judgement criteria when applied to projects of a similar nature. In this case the variation was best described by individual rating style. However, it would be possible to use this method to assess whether there are any systematic differences in the way the experts are working. For example, to decide whether raters with different backgrounds were able to make finer distinctions owing to their particular expertise.

CHAPTER TWO:

MODELLING GROUP DECISION MAKING: PILOT STUDY

Using a hypothetical decision problem concerning student housing with two groups of volunteers the pilot study shows how the elicitation and representation techniques can be used to model both the task and the process of group decision making.

Similarities and differences between a series of qualitatively different decision options are elicited from each group of decision makers using the facetted sorting procedure. The combined knowledge of group members is then represented using Multidimensional Scalogram Analysis (MSA).

MSA plots the decision options as points in geometric space so that the more qualities two options have in common the closer together they appear in the two dimensional plot. This allows the decision task to be represented in terms of those issues thought to be important by the group members. The reasons for similarities and differences between the decision options are shown as overlapping regions within that space. Since the qualitative constructs generated by the facetted sorting procedure are attributable to individual members of the group, the role each person's views played in the final decision can also be modelled thus reflecting the group processes.

Comparison of the group's decision to the MSA representation shows that it is possible to model the group decision in terms of both task and process. This modelling is most successful when an open ended sorting task is used to elicit information from the group members.

CHAPTER TWO:
Modelling Group Decision Making: A Pilot Study

2.1 Introduction

The elicitation (facetted sorting procedure) and representational (Multidimensional Scalogram Analysis) techniques for group decision making (full details can be found in the technical appendix at the end of this report).

A hypothetical decision problem was selected for which anyone could be considered an expert. This decision problem concerned the selection of properties for student housing, and four small groups of six people were recruited for the study. Each group decision exercise was conducted under different conditions so that both the interventions, ie the elicitation and representation techniques, could be compared to a group with no intervention.

The aim of the research then, is to elicit, and represent the knowledge of the group members with respect to the decision problem. If the representational system can adequately reflect both the task and the process dimensions of the group decision, then it holds the potential for decision support when fed back to the decision making group.

2.2 The Representation of Task and Process for Group Decisions

The representations used have two qualities which it has been hypothesised will improve the decision making process. Firstly, representation of the relationship between the properties themselves, with respect to each of the relevant variables should have an impact on the ease of the actual task presented to the decision makers. It is hypothesised that such a presentation would improve task dimensions such as problem solving and task focus.

However, the MSA representation also has the capacity to illustrate the differences and similarities between different group members' perceptions of the decision structure, in terms of the attributes which each person feels applies to each of the properties. This second dimension of feedback to the group suggests that the representational system would improve process dimensions of the group decision making eg communication.

2.3 The Decision Problem

The problem presented to the group was one involving a choice of properties for student housing. The group were given a selection of sixteen estate agents' particulars of properties in the Guildford area. All the properties were of a similar size and price, but varied in age, location, and accommodation offered. A budget of £500,000 was allocated to the group to spend as they wished, and the participants were asked to familiarise themselves with the properties so that at the group meeting they would be in a position to contribute their personal opinions as to which of the houses they should purchase.

Each participant was given a document introducing them to the project and detailing the hypothetical decision which they would be required to make. The group members were told that they were to role play members of a committee which was being brought together to decide which of a number of properties to buy in order to house university students off campus. So that each person would have a different perspective to role-play at the meeting, they were assigned different roles. Each member of the group was given a brief description of their role and the aims of that person at the meeting.

The roles which were given to the participants are shown below.

Student Representative

You have been elected by the students union to represent the students needs in the new housing scheme. You have been asked to
make sure that issues concerning those who will live in the houses are addressed. The types of issue which would be important to the students have not been suggested to you. It is up to you to think of the things which might be important to the residents.

Finance Officer

The University has decided to spend a large sum of money on student housing. You have been sent to join a decision making group to ensure that the best possible deal is reached financially. Your concerns are with getting the best deal possible within the budget. The criteria for a good deal must be established by the group.

Housing Officer for Liaison

You work in the accommodation office. You are used to dealing with student problems and have much experience of the types of problems faced by both landlords and tenants. You are concerned with selecting the best possible practical solution, by buying the right houses from the start. Any aspects of the properties selected which may lead to disputes between residents or practical problems which the university may have to sort out are of prime importance to you.

Housing Officer for Maintenance

You work for the accommodation office. Your duties in the past have involved arranging for repairs and maintenance of both university property and private lets to students. You are aware of the kinds of practical problems faced in building maintenance. You have been selected for the committee to ensure that practical considerations are taken into account when the properties are selected.

Estate Agent Representative

You work for a well known estate agent in Guildford which the university has selected to work on this deal. The scheme is worth a great deal of money to your firm, and it is important that the University is satisfied with their purchases to encourage any further work in the future. Whilst you want to present all the possible properties in a good light, you do

not want to sell the group anything which may turn out to be unsuitable.

Chairman

You have been voted the chairman of the group. Whilst people will be interested in your personal opinions too, your main task is to ensure that the decision is made in the time limit of the discussion group. You are responsible for keeping some order in the group and in making sure that all the relevant issues are considered.

The remainder of the instructions presented to the participants varied according to the experimental condition to which they had been assigned.

2.4 Experimental Conditions

No Representation	Representation
Group 1	Group 2
No Intervention	Free sort (own categories)
Group 3	Group 4
Structured sort (provided categories)	Structured sort (provided categories)

Condition 1 (Group 1)

In the first condition the group was asked to make the decision without any prior elicitation, or any kind of representation during the group discussion. Participants in the control, or 'no intervention' group were simply given the properties to examine before the meeting so that they had a similar level of knowledge about the properties as the groups who had sorted them prior to the group discussion.

Participants: The participants in this condition were all female members of the secretarial and administrative staff of the psychology department.

Condition 2 (Group 2)

The second group were asked to make the decision using both the elicitation and representational techniques. Participants in Group Two used an open-ended (own categories) facetted sorting procedure for elicitation.

This condition reflects the type of problem for which the group has no predetermined criteria

on which to judge the entities, and the relevant variables must be defined by the members of the group. These variables, are however, categorical. The MSA representation will allow the entities to be represented in relationship to one another with respect to these criteria which can established by the individual group members. Therefore the MSA will provide the group with a representation of both the criteria which each member believes to be important in distinguishing between the possible options along with their perceptions of which of these entities fall into each category.

Members of group two were asked to sort the properties into groups according to any criteria which they felt to be important to the decision. They were allowed as many categories as they liked and as many groups as they liked. This data was analysed prior to the group meeting using MSA. Once guided through the principles of MSA the participants were left to use the plots in any way they wished.

Participants: The members of Group Two were all male technicians working together in the same workshop in the department of mechanical engineering.

Condition 3 (Group 3)

The third condition compares with condition 1, no intervention, in that no representation was presented to the group to work with during the decision. However, the group were asked to participate in a structuring sorting procedure using the same provided categories as the members of group four (see below). This allows the impact of the actual sorting procedure to be assessed in terms of its effect on the group, independently of the representation.

As part of their introduction to the study, the members of group were asked to sort the properties into groups according to two predetermined criteria in keeping with their role. They were asked to categorise the properties into three groups on each of the attributes, which were to be their concerns at the forthcoming meeting. On arrival at the group meeting they were presented with a list of their categorizations, and allowed to proceed with the decision as they wished.

Participants: The participants in group three were a group of mixed sex post graduate students from a number of subject areas, most of whom had met socially. Only five people took part in this group, the 'Estate Agent' not being represented.

Condition 4 (Group 4)

The conditions for Group Four were very similar to Group Two, only the elicitation was based on provided categories.

In this condition the group decision is based on a problem in which the criteria for the selection have been predetermined. In such a decision making situation, established categories for the experts to use in their decision making may come from previously established norms, or possibly from others within a hierarchical decision making structure. The MSA therefore represents the entities according each of the expert group member's assessment of them on each of the predetermined attributes.

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Participants in this condition were given the same instructions as those in group three, being required to sort the properties in terms of two provided criteria which were to be their concerns at the meeting. This data was analysed using MSA and presented to the group members in the same format as for condition two.

Participants: The members of group four were all male technicians from the engineering department. However, their jobs varied from chief technician in electronic engineering, to skilled draughtsman in mechanical engineering, to those working in stores and supplies.

2.5 The Group Decisions: An overview.

i) The Outcome

The properties which were eventually chosen to be bought with the budget by each of the four groups are shown in Table I.

Table I. Properties chosen by the four groups.

	Properties Chosen					
Group 1	4	5	7	8	10	16
Group 2	4	5	7	8	6	16
Group 3	11	12	7	8	6	14
Group 4	4	5	3	8	6	16

Table I shows that the final decisions made by the groups were actually very similar. Three out of the four groups chose properties, 4, 5, 6, 7, and 16, and all four groups placed property 8 in their final selection.

It could be suggested that these results reflect the ease of the decision. If the task is used in future studies it could be modified to make the decision less clear cut. For example, none of the two bedroomed properties were considered by the groups, and none of the properties located outside the Guildford area were chosen. Making the entities more homogeneous would make the decision more difficult, and thus the test of the method more rigorous.

Nevertheless, the similarities and differences in the final selection of properties is particularly interesting. Whilst the four groups did come to similar decisions, the slight variations in their choices show that the task selected for the research is sensitive enough to pick up differences between the groups. Future research will be able to examine the group discussion more closely, so that the stages which certain groups go through in choosing certain properties can

be related to the group processes, for example, communication and leadership. For example, a certain property might be chosen purely on the basis of the criteria used by one dominant member of the group.

ii) The Group Discussion and Use of the Representations

Although the four groups of participants came to very similar decisions in the end, it is also useful to examine the way they went about making the decisions, and the role of the representation and elicitation procedures.

a) Groups 2 and 4

The two groups who were given MSA representation were not given instructions as to how to use the MSA to make their decision, in order to examine the way in which naive users might try to use the representations.

Observation of the two groups given the MSA representations showed that they did use plots in a way which may have helped with their decision.

The members of Group Two wrote the sub-categories of each criteria which were associated with each instance onto the top plot, so that they could see the qualities of each property at a glance. This group went on to then dismiss the properties 'on the right hand side' since they were all two bedroomed. This is a clear example of the way which the similarities between the entities can be used to help the group on the task dimension.

The members of Group Four used the representations by 'flipping' between plots to compare the attributes of each property.

One noticeable feature of the decision making strategy of these two groups was their systematic approach to the consideration of the group members' views; both groups went round the table asking each member what their criteria (opinions) were, and which instances they had placed in their best categories.

b) Groups 1 and 3

The systematic way in which the views of group members were assessed was also reflected in the way in which group 3 conducted the group meeting. Although given no representation this group used the categories they had created in the facetted sorting procedure in a very systematic way. They first established the order of importance in which the attributes of the properties should be considered, and then went through them systematically excluding those which fell into each of the 'worst' category until they had reached a stage where the correct number remained. In fact this group started to construct matrices of their classifications which, if successful, would have been comparable to those which could have been analysed using POSA or MSA.

However, this stands in marked contrast to the approach adopted by the members of group 1, (no intervention), who covered issues and properties quite arbitrarily until a decision was

reached. Towards the end of the session, some group members were still asking which of the properties had been excluded and why. The time taken to make a decision by Group 1 was also considerably less than the other groups (see table II), suggesting that less consideration was given to the alternatives despite the group's satisfaction with the decision making process.

Table II

Group 1	29 mins.
Group 2	59 mins
Group 3	45 mins
Group 4	49 mins

Table II. Time Taken by Each Group to Reach Decision.

2.6 Modelling the Group Decision

By examining the MSA plots for each of the groups, it is possible to gain some first impressions as to the utility of the representational techniques in reflecting the task and the process dimensions of the group decision.

Although these initial studies represent a very early stage of the development of the research, the way in which the group's eventual decisions are reflected in the MSA representations give some valuable insights into the potential of this system for further development.

The overall configuration of the MSA plot is derived from the classifications made by each member of the group in the facetted sorting procedure. Examination of the contribution of each group member's opinion to the overall plot, and comparison with the groups' eventual decisions shows the extent to which each individual member's classifications were reflected in the group decision.

To demonstrate the way in which both the product (the properties chosen) and the process (the group members' contributions) can be modelled using the MSA representations it is necessary to examine in some detail the MSA output from Groups Two and Four.

i) Group Two

The overall MSA plot of properties generated from the free sorts done by the members of Group Two is shown in Figure 1, the properties eventually chosen being represented with 'O'.
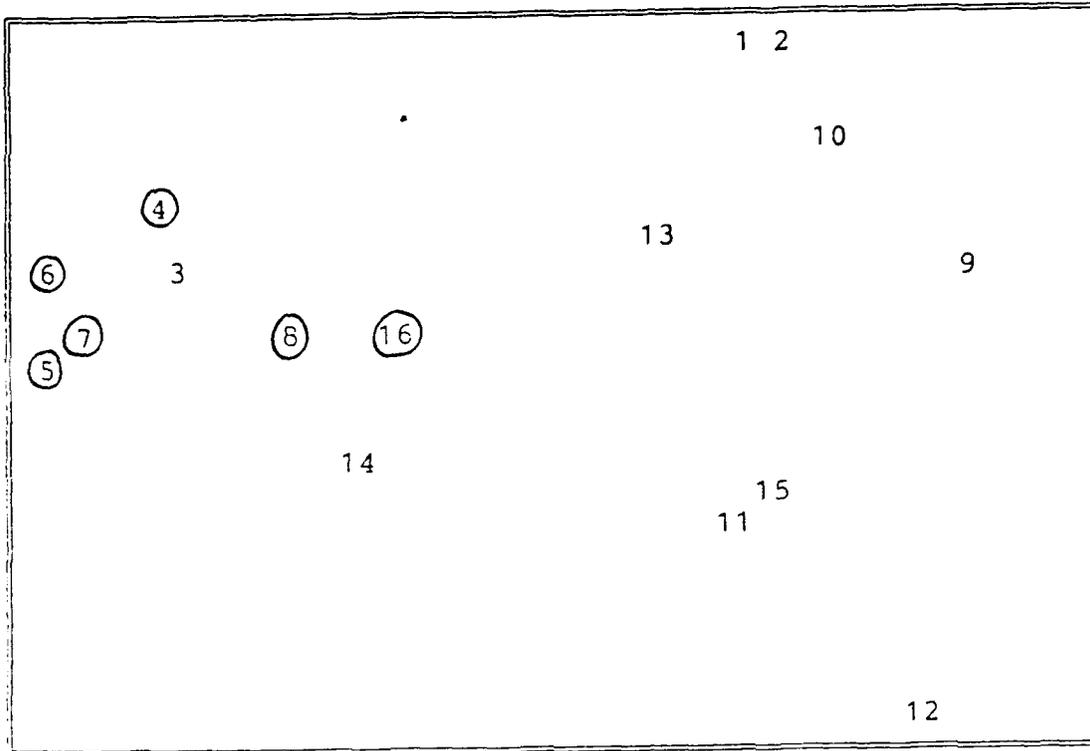
Figure 1. Group 2. Overall MSA plot showing the sixteen properties and the six properties eventually chosen by the group (circled).

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The overall configuration of points reflects the similarities and differences between the properties according the opinions of all the group members. The properties which were eventually chosen by the members of Group Two are circled in the plot (Fig. 1). The properties chosen by this group are very similar to each other across the criteria thought to be of importance by the group (and are therefore close together in the plot).

The item plots for some of the attributes considered to be important by the group members are shown in Figures 1a to 1f. In each plot the class of properties thought to be the least suitable has been shaded in, to encompass the properties which have effectively been excluded in that person's opinion.

Figure 1a shows the properties divided according to the number of bedrooms. This way of classifying the properties was used by three of the group members, and was considered to be the most important factor in selecting the final solution by the group members.

Such a categorization would exclude all the properties on the right hand side of the plot. This was indeed the first thing which the group did. Distance from the University was considered to be another important factor in the decision and Figure 1b shows the properties excluded by the maintenance officer in his assessment of the suitability of the locations, and Figure 1c shows the distance of the properties as assessed by the Student Representative.

The Estate Agent considered the age of the properties to be an important consideration and his divisions according to Modern and Old houses is shown in Figure 1d. The second criteria used by the Estate Agent was the manageability of the gardens, and the plot demonstrating his categorizations of manageable and unmanageable is shown in Figure 1e.

Finally, Figure 1f shows the maintenance officer's classifications of the properties according to the type of heating in the property.

If each of the group members' least suitable category is shaded in and the item plots for the attributes of the properties which were considered to be the most important to the decision are superimposed, the properties which do not suffer from any of the group members' restraints are shown in the unshaded area (Figure 2).

This representation demonstrates that the properties chosen by the group were indeed selected in a very rational way given the concerns of the group members. The properties chosen (shown in circles) are located in the least number of shaded areas, according to the these group members' exclusion rules.

This illustrates the value of the representation in demonstrating the qualities of the properties, ie the task dimension. Thus the plot demonstrates the properties which are the most similar in terms of the criteria selected by the group. Further, the coherence of the positioning of the properties in the plot shows that the plot accurately represents the qualities of the properties which were considered by the group in making their decision.

When the process dimension of the group decision is considered, the final plot is also quite revealing.
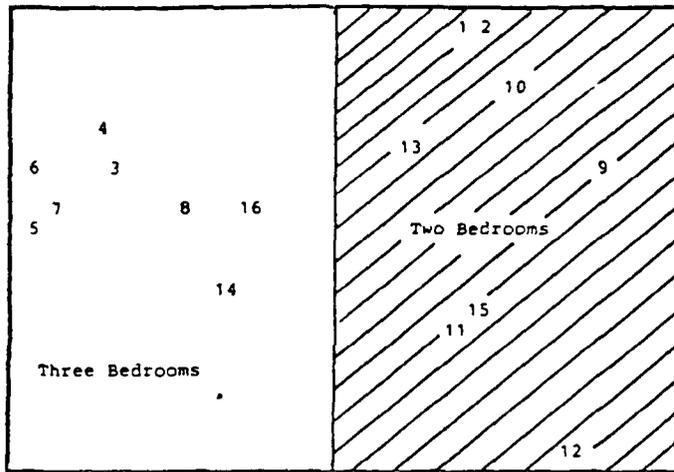
Figure 1a. Group 2. Item plot showing the Chairman's classification of properties with one and two bedrooms.
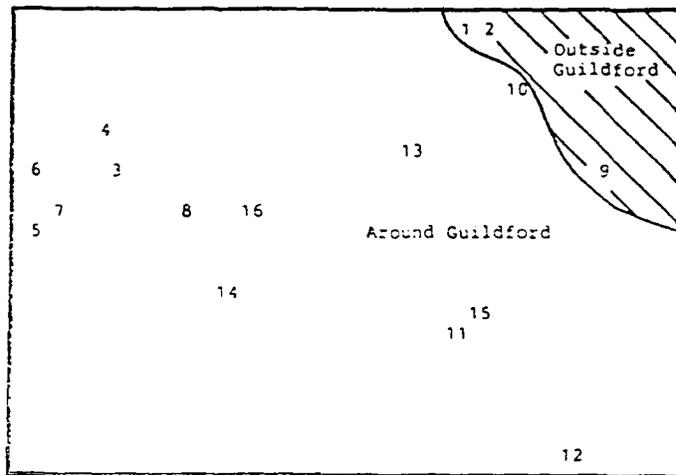
Figure 1b. Group 2. Item plot showing the Maintenance Officer's classification of properties outside Guildford, and around Guildford.
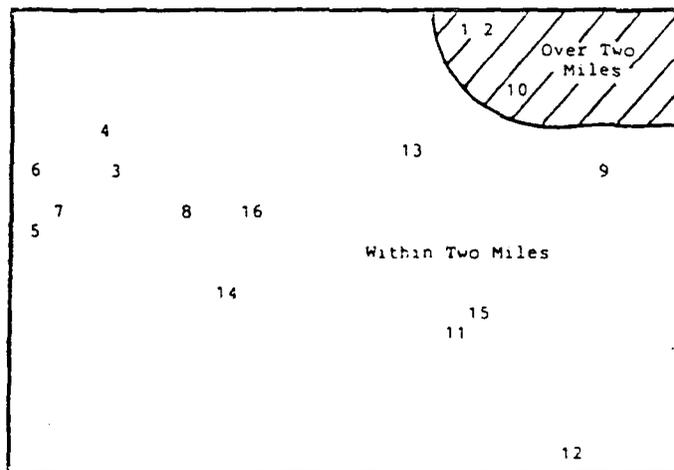
Figure 1c. Group 2. Item plot showing the Student Representative's classification of properties within and over two miles from Guildford.
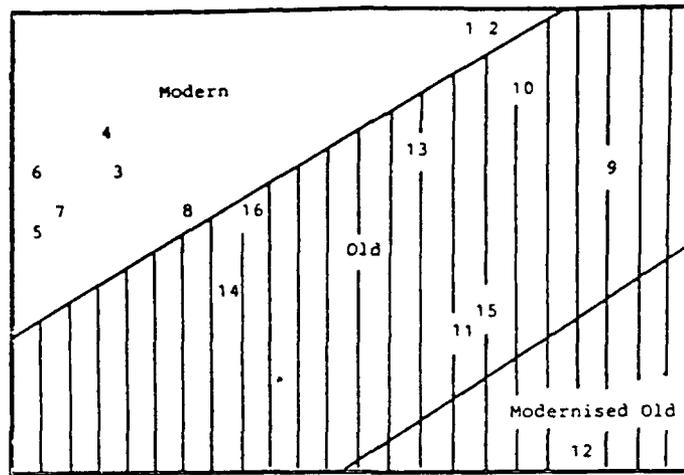
Figure 1d. Group 2. Item Plot showing the Estate Agent's classification of Modern, Old and Modernised Old properties.
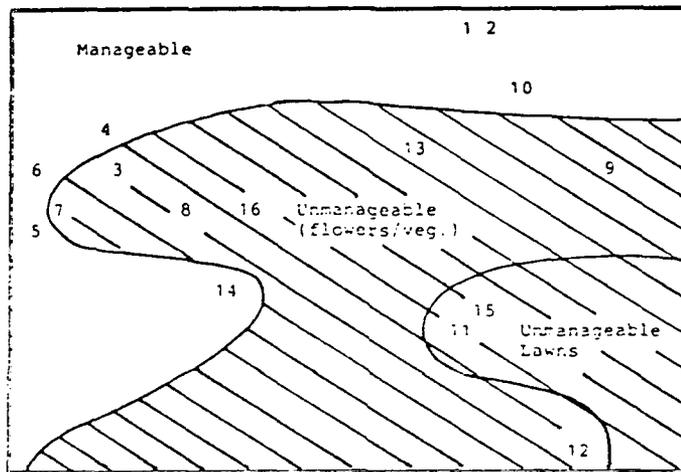
Figure 1e. Group 2. Item plot showing the Estate Agent's Classification of Manageable and Unmanageable gardens.
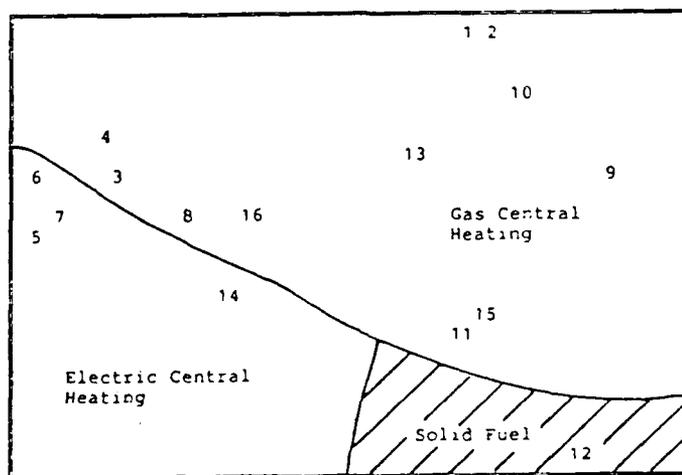
Figure 1f. Group 2. Item plot showing the Maintenance Officer's classification of the type of Heating in each property.
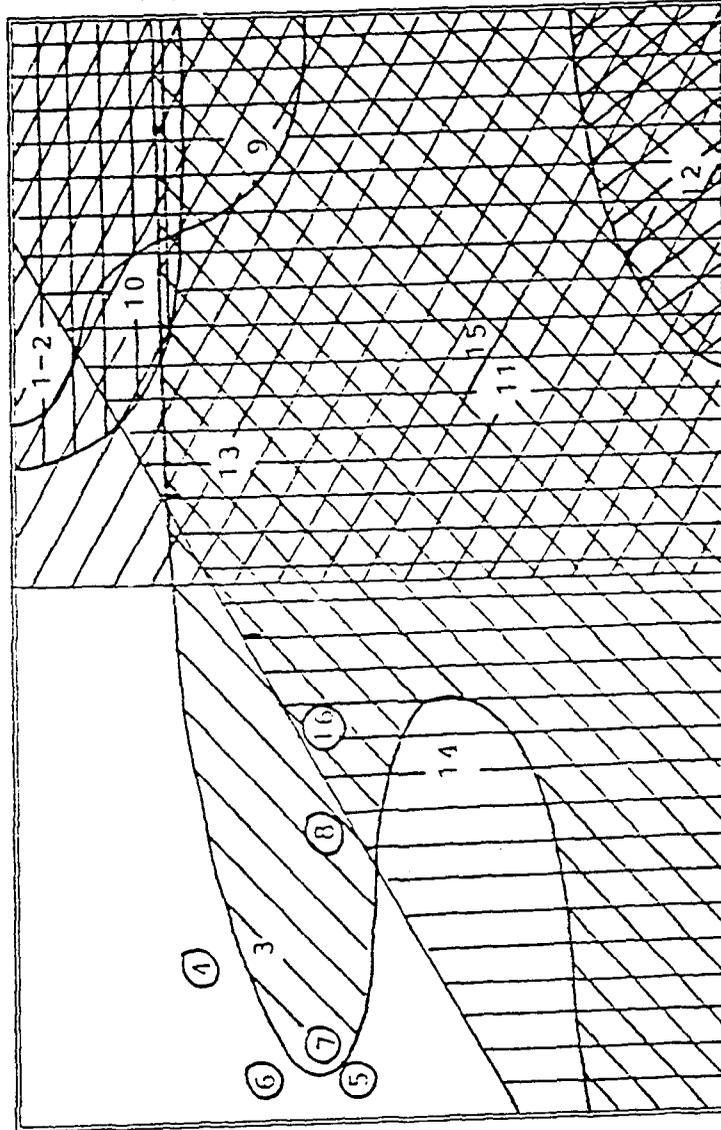
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Figure 2. Group 2. Overall MSA plot showing the sixteen properties, the group members' exclusion rules, and the properties eventually chosen.

By comparing the item plots for two of the group members it is possible to quickly identify any areas of disagreement between them. For example, comparison of Figure 1b and 1c show that although the Maintenance Officer and the Student Representative both considered a number of the properties to be too far from the University, they actually disagree about properties 9 and 10.

Given the group members' classifications which are shown here, properties 7, 8, and 16 were chosen even though they are located in the Estate Agent's group of properties with unmanageable gardens. Further, the Estate Agent's view that old properties should not be purchased was also over-ruled by the group with respect to property number 16. This suggests that the participant who played the role of the Estate Agent had little say in the final decision. This finding can be related back to the group discussion, in order to examine just why these properties were accepted against the Estate Agent's recommendations. Additionally, future research will be aimed at validating the group modelling with reference to the participants' rating of the group decision (see Chapter Four).

ii) Group 4

The overall MSA plot based on the structured sorts done by group four is shown in Figure 3, along with the properties which were eventually chosen by the group (O).

In contrast to the coherence of the properties chosen by the members of Group Two, the properties chosen by Group Four are more spread around the MSA plot. This shows that the properties which were eventually chosen by the members of group four were not similar on the dimensions used for the MSA. That is, although the categories which were provided for the group to use were used to model the decision making process, the model does not reflect the decision made by the group. This suggests that whilst the group were given criteria to divide the properties and to make their decisions according to, the actual properties chosen do not reflect this. It is most likely then that the group were working with distinctions other than those they were given. This finding has important implications for research working with provided rather than elicited categories and will be the subject of further research.

Of the attributes they were given, group three felt that distance from the University was one of the most important. Two of the group members (the student representative and the Estate Agent) were given distance as a criterion to consider and their assessment of the suitability of the location. Figures 3a and 3b show the item plots which show these two group members views.

Comparison of the two plots reveals that the student representative is more stringent in his view of what can be considered a suitable distance than the estate agent. Whilst the student representative has six properties in their 'furthest away' group, the estate agent has only three. However, both the group members are agreed that properties number 1, 2 and 10 are too far away from the university to be considered.
The housing officer's opinion of properties which are located in an unsuitable neighbourhood is reflected in the partitioning of Figure 3c. Comparison with Figure 1a shows that the most unsuitable properties were largely those which had already been excluded by distance from
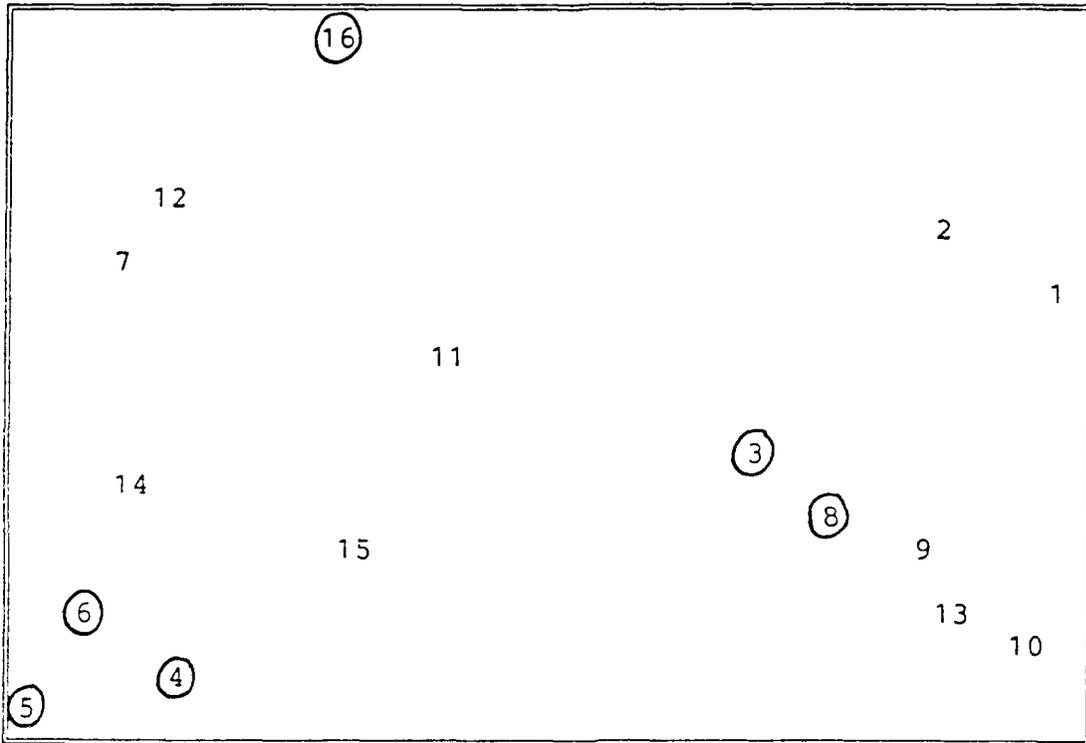
Figure 3. Group 4. Overall MSA plot showing the sixteen properties, including the six which were eventually chosen by the group.
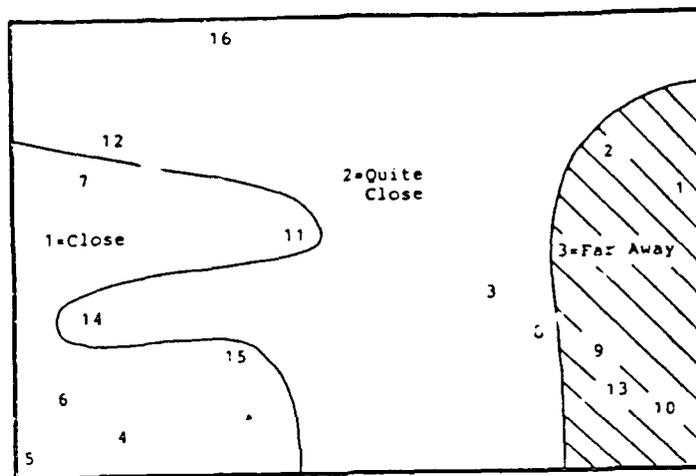
Figure 3a. Group 4. Item plot of Student Representative's classification of properties which are close (1), quite close (2), and far away (3) from the University.
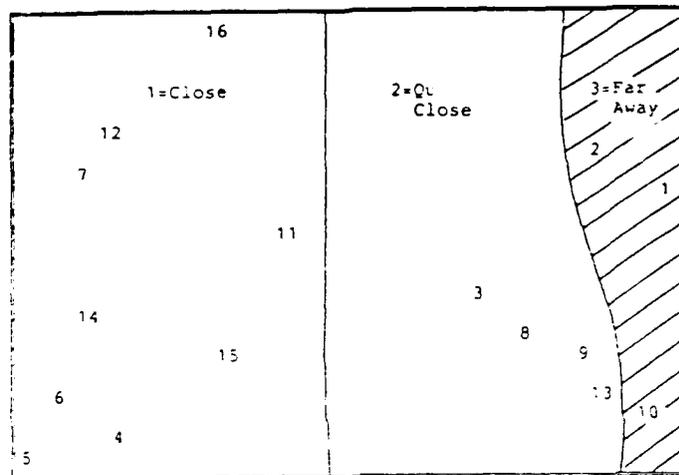
Figure 3b. Group 4. Item plot of Estate Agent's classification of properties which are close (1), quite close (2), and far away (3) from the University.
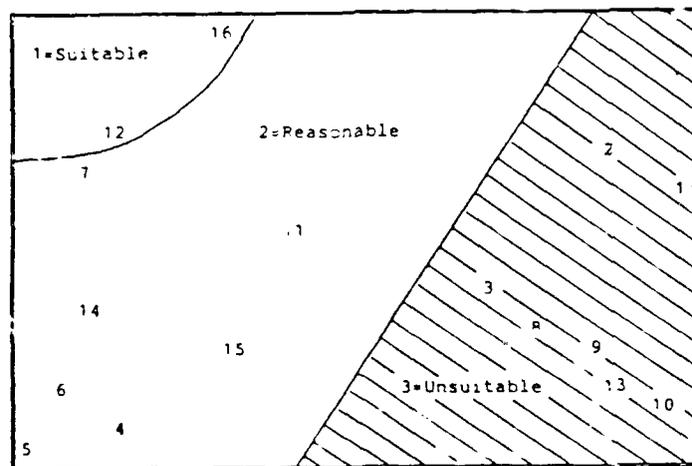
Figure 3c. Group 4. Item plot of the Housing Officer's classification of suitable (1), reasonable (2), and unsuitable (3) properties in terms of neighbourhood.

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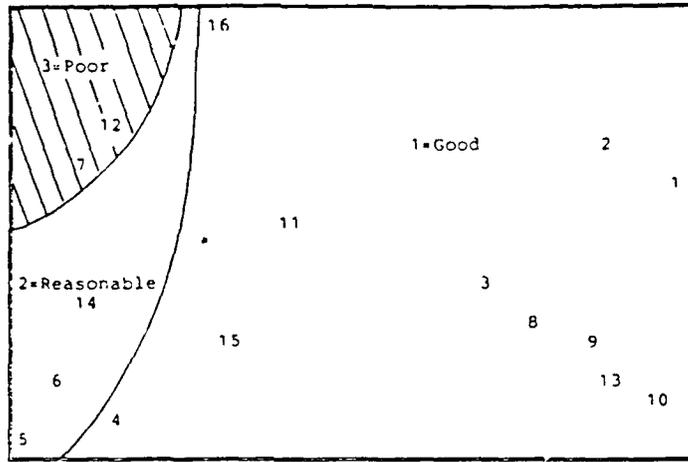
Figure 3d. Group 4. Item plot of Housing Officer's classification of good (1), reasonable (2), and poor (3) heating facilities.
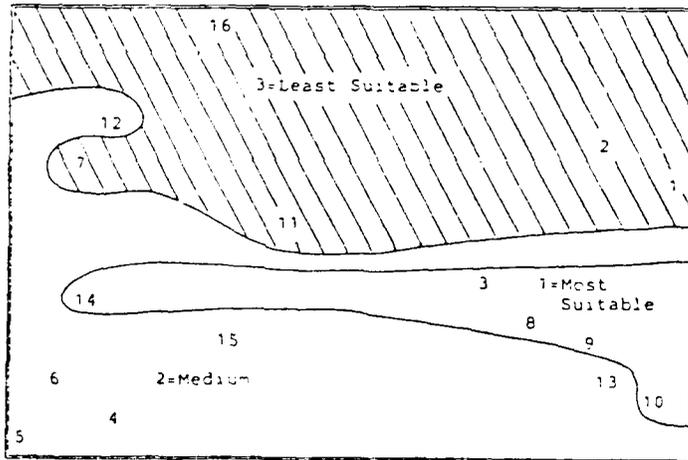
Figure 3e. Group 4. Item plot of Maintenance Officer's classifications of suitable (1), reasonable (b), and unsuitable (3) properties in terms of general condition.
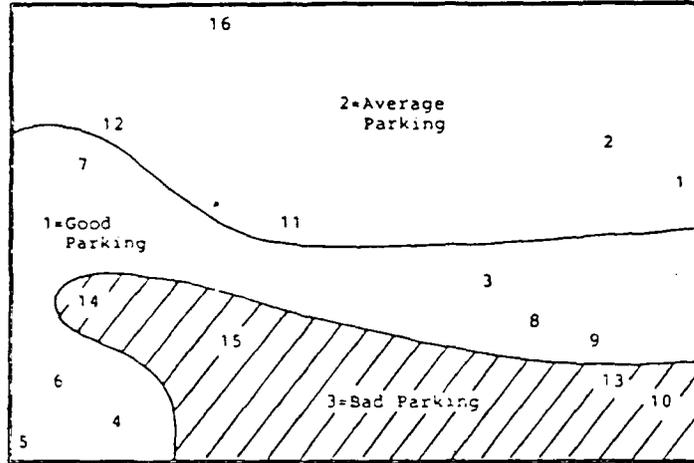
Figure 3f. Group 4. Item plot of Estate Agent's classification of Good Parking (1), Average
Parking (2) and Bad Parking (3).
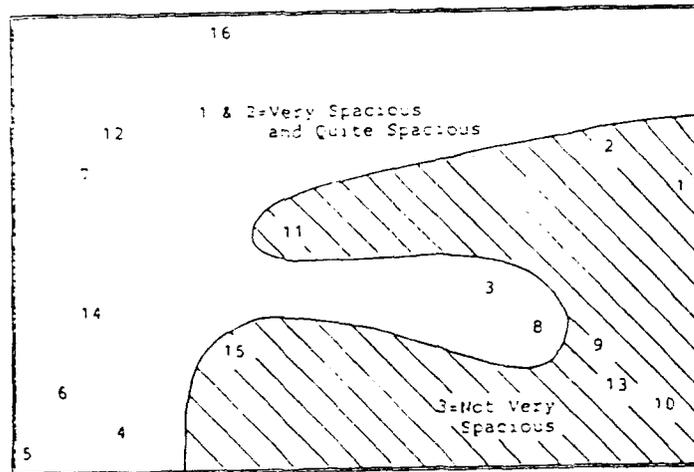
Figure 3g. Group 4. Item plot of Student Representative's classification of properties which
are very spacious (1), quite spacious (2), and not very spacious (3).
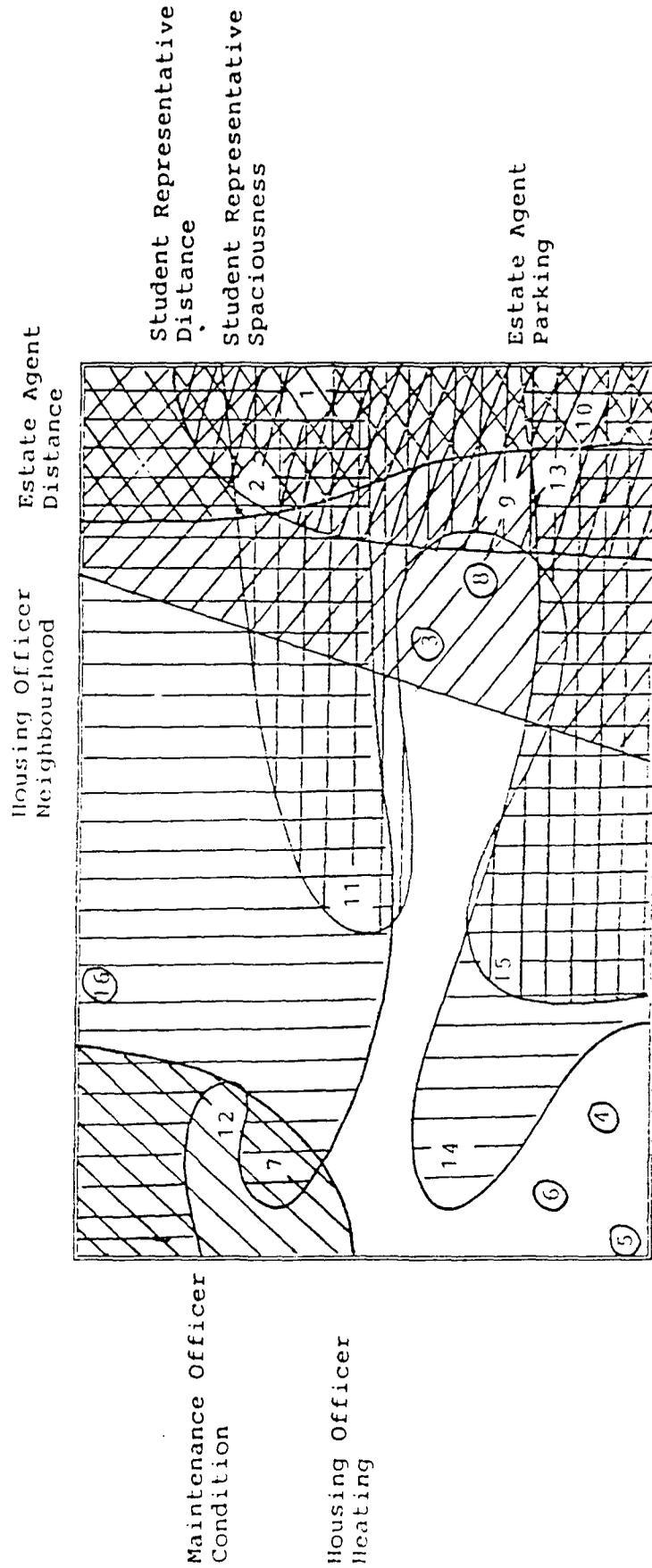
65

Figure 4. Overall MSA plot showing the sixteen properties, the group members' exclusion rules, and the six properties eventually chosen by the group.

the university.

The maintenance Officer's classifications as to the suitability of the properties' condition is shown in Figure 3e, and the Estate Agent's views on the availability of parking can be seen in Figure 3f. The spaciousness of the properties was used as a classification scheme by the student representative and this item plot can be seen in Figure 3g.

The concerns of the housing officer regarding the heating system were discussed at some length, and the group decided that his opinion that properties 7 and 12 be excluded was upheld (see figure 3d).

Figure 4 shows the combined plot and demonstrates that although properties 4, 5 and 6 were selected from the region of most suitable properties, properties 3 and 8 were chosen, even though they did not meet some of the group members' criteria. In cases like this it would be particularly important to assess the decision pattern more closely and the group processes such as leadership etc in order to find out the underlying group processes which result in some people's criteria not being met.

2.7 Conclusions

The pilot studies with the hypothetical decision problem have revealed some very important conclusions regarding the elicitation and representation techniques.

1) The pilot studies have provided some general indications of the way the elicitation and representation procedures can be used by live discussion groups, compared to the purely theoretical applications which we have previously explored.

2) The comparison of provided and elicited categories in the facetted sorting procedure has suggested that elicited categories may more accurately reflect the group's knowledge. This has pointed to a very valuable area for future research.

3) The most important result of the pilot studies has been the success of the modelling of the group decision using the elicitation and representation techniques. The fact that both the product of the decision making group, and the process of establishing that decision can be modelled in the representation is of major importance to the further development of the system for decision support.

CHAPTER THREE

THE DEVELOPMENT OF THE QUESTIONNAIRE

A questionnaire is developed as an instrument to measure people's experience of group decision making. The questionnaire is developed on the basis of pilot data to measure participants' perceptions of communication, leadership, group cohesion, problem solving, task focus perceived success and personal involvement.
The questionnaire has three applications:

> a) to measure people's satisfaction with the task and group processes in comparative studies of decision making.

> b) to allow comparison between the objective modelling of the group using MSA with the subjective opinions of the individual members, eg to compare the actual input a person has into the decision with their perceptions of their input.

> c) to contribute to the feedback system itself by representing the group members' perception of the decision making group.

CHAPTER THREE
The Development of the Questionnaire.

3.1 Introduction

As part of the work on group decision making it was necessary to develop a questionnaire to assess people's perceptions of the decision making experience.

Three requirements of the questionnaire have been identified. Firstly the questionnaire will be able to assess the differences between groups who had been presented with feedback in the form of the representations and those who had not.

Secondly, obtaining measures of the psychological variables of group decision making will give a measure of the perceived input which each individual has made to the decision, and thus allows the comparison with the modelling of the group decision revealed in the MSA plots. Thus, for example, a subjective measure of the group members' contribution can be compared with the objective dimensions shown by mapping the group members' views onto the plots discussed in the final report for year one.

Finally, the similarities and differences between the group members' perceptions of the decision making group will be represented, along with their perceptions of the way in which the group dealt with the problem, allowing a thorough analysis of the whole system in terms of group dynamics.

To fulfil these objectives a pilot questionnaire was developed, and following the group decision making exercises held to far, each member of the group was asked to fill in a questionnaire rating their perceptions of the group on a number of dimensions. The questionnaire was designed to assess the group process dimensions of group coherence, communication and leadership. Task variables of problem solving and task focus were also addressed.

In addition to measuring the task and group variables, items were also included on the questionnaire which give an indication of how satisfied each member of the group was with the decision overall, and their feeling of involvement in the decision making process.

3.2 The Pilot Questionnaire

The questionnaire which was developed at this stage in the research was a pilot questionnaire and the attitudinal items included on it were only hypothesised to measure the group variables. Therefore the data gathered from the groups so far can be used to test whether or not the questionnaire items do measure people's perceptions of the task and process variables outlined above. This analysis is essential for the development of a reliable instrument for measuring the group experience which can be used in further research.

The items on the questionnaire took the form of statements about the group, the decision they

had made, and the way in which the discussion had been handled. The respondents were asked to rate their agreement with each statement on a five point scale from strongly agree to strongly disagree. The statements were devised on the basis previous research in this area, and the work of previous authors was consulted in order to give an indication of possible attitudinal measures of the areas being studied.

The statements which were devised are shown in Table I, according to the hypothesised measure of each of the task and process variables being studied.

3.2.1 Communication

The items associated with communication are of particular interest to the research. The research undertaken last year has shown that the MSA plots are able to model both the task itself, in terms of the similarities and differences between the decision options with respect to the decision makers' opinions of them, and the views of each individual member about the suitability of the solutions to the decision problem. By assessing the individual group member's perceptions of the input they have had in the decision, it will be possible to compare their ratings of the communication in the group to the MSA plots, which reveal their actual input with respect to the factors they regard as important.

Further, it has been hypothesised that the MSA plots, when used as feedback to the group, will be of benefit to the communication process. Thus it is necessary to measure the satisfaction with the communication processes in order to test the utility of the feedback system.

The items hypothesised to be associated with communication are shown in Table I. The items contain both positive and negative statements in order to avoid response set bias.

The first five statements consider the individuals' perceptions of their own input to the discussion, the ease with which they were allowed to speak, their perceptions of the equality of the expression of opinions and their representation in the final decision. Statement C6, was included as a possible measure of the type of communication network, assessing whether the opinions were being directed through the nominated group leader. The final statement was included to measure the success of the communication system being taken, it being hypothesised that not understanding the discussion would be a result of poor communication.

3.2.2 Leadership

The statements included regarding the leadership were designed to assess the strength of the leadership within the group (eg Leana 1985). That is whether a leader emerged (L4), whether the group was 'underled', resulting in little structure to the discussion (L2, L3), or 'overled', the leader influencing the discussion themselves (L1). Finally, the impact of leadership on the group's communication was also included, to assess the extent to which people were encouraged to contribute (L5), or the extent that the discussion was allowed to be dominated by certain members of the group (L6).

These items are of particular interest to the modelling of the group process in terms of the actual influence which people had on the decision solution. Further it allows comparison of

groups who had more or less leadership.

3.2.3 Cohesion

The cohesion of a group has received much attention in previous research with a great deal of work springing from Janis's notion of 'group think' (Janis 1982). His work suggests that groups who are highly cohesive are in danger of making poor decision since their is less chance of viewpoints being challenged (Item Ch1).

The cohesion items also relate directly to the development of the modelling techniques, as the MSA plots give a direct indication of the agreements and disagreements of the group members with respect to the decision. The items included in this section measure the group members' perceptions of the cohesion of the group which can be compared to their actual level of agreement with respect to the decision problem.

The items selected to measure cohesion were developed on the basis of a number of previous research papers consulted on group cohesion (eg Leana 1985; Callaway and Esser 1984).

3.2.4 Involvement

The degree to which an individual feels involved in the group decision making has also been considered by past research and it was hypothesised that the statements selected below would measure involvement. Emotional response to the group decision making exercise has been one measure taken by previous research (eg Guzzo and Waters 1982) and items I1, I3, and I4 reflect this. Whether the task was enjoyable and whether it was taken seriously are also considered to be indicators of the involvement of the group in the decision making exercise.

3.2.5 Success

The two items shown in the Table I were included in the questionnaire as a measure of the individual member's perceptions of how successful the group decision making had been. The respondents' rating of the success of the decision making can be related to the other measures in order to analyse which aspects of the group decision making are most related to satisfaction with the outcome.

3.2.6 The Task

The three task items were included purely as a measure of the clarity of the task which the group had been given. They were designed to assess the suitability of the decision problems given to the groups, in terms of whether the task was comprehensible to the participants, and whether they were possible based on the information given (Pflum and Brown 1984).

Table I

Leadership
L1 The group's decision was influenced by a dominant leader.
L2 The group would have benefitted from a good leader.
L3 The discussion lacked structure or direction.
L4 The group developed a clear leader.
L5 The leader encouraged me to express my opinions.
L6 Certain individuals dominated the discussion.

Communication
C1 Everyone's opinions were given an equal hearing.
C2 My ideas were not taken into consideration in the final decision.
C3 My views were represented in the final decision.
C4 The group allowed me to express to views.
C5 I found it difficult to get my views heard.
C6 Opinions were generally addressed through the group leader.
C7 I didn't understand some of the directions that were being taken.

Coherence
Ch 1 Once people made up their minds they were reluctant to change them.
Ch 2 I made some compromises for the group
Ch 3 There were many disagreements between the group members.
Ch 4 Conflict existed between some members of the group.
Ch 5 I liked working with this group.
Ch 6 The group worked together efficiently.
Ch 7 This group does not work well together.
Ch 8 I did not feel as though I was a part of the group.

Involvement
I1 There was a high level of energy in the group
I2 I enjoyed the group discussion.
I3 There were times when I felt quite angry.
I4 People got quite personally involved in the decision.
I5 The task was taken seriously.

Success
S1 We chose the best possible solution.
S2 The solution we chose was the most practical one.

Task/Information
T1 We had enough information to make the decision.
T2 I understood the task clearly.
T3 We needed the input of specialist information.

Focus
F1 We could have done with more focus on the task in hand.
F2 The group got involved in irrelevant discussion.
F3 The discussion was focused around the problem in hand.
F4 We did not have enough time to make the decision.

Problem Solving
P1 Others contributions were used to build new ideas.
P2 All the possible solutions were given consideration.
P3 A wide range of alternatives were explored.
P4 Evaluation of the solutions was done in a systematic way.
P5 The group had clearly focused objectives from the start.
P6 Rejected solutions were reconsidered towards the end.
P7 We narrowed down the possible solutions early on in the discussion.
P8 The acceptability of each solution was discussed.

Table I. Questionnaire Items Within Each of the Task and Group Process Domains.

3.2.7 Task Focus

Items F1 to F4 were designed to measure the amount of focus the group had on the problem itself. These items measure the group's attention to the problem, whether there was irrelevant discussion in the group, and whether the members felt that there was too little time to make the decision.

3.2.8 Problem Solving

There has been much research on the type of problem solving strategies employed in group decision making and there is some agreement on the types of problem solving approaches which are likely to result in thorough consideration of the decision problem. Drawing on previous work (eg Guzzo and Waters 1982), statements P1 to P8 were included in order to measure the extent to which the participants rated the group's approach to the solving the decision problem as following these 'ideal' formats.

Summary

A pilot questionnaire consisting of forty-three attitudinal statements was devised in order to address the group members' perceptions of the processes of communication, cohesion, leadership within the group; the ease of the task, the focus and problem solving strategies of the group; and the success of the outcome.

3.3 Analysis and Results: Rephrasing the Questionnaire.

Data has been gathered from thirty seven questionnaires issued to all the participants in the research so far. This data was analysed in order to assess whether the questionnaire items measured the group decision making areas which have been hypothesised.

The aim of the analysis is to examine the questionnaire items in detail on the basis of the pilot data, so that the questionnaire can be developed into a reliable instrument which will measure the group process and task variables of decision making.

The data available from thirty-seven participants in the research so far is drawn from seven decision making groups. Two types of examination of the questionnaire data are presented, firstly the rephrasing of the questionnaire statements which was deemed necessary on examination of the means and standard deviations, and secondly how appropriate the items are with respect to each of the decision making domains, analysed using Smallest Space Analysis (SSA) (See section 3.4.1).

Examination of the means and standard deviations of the participants' response to the questionnaire items is essential in piloting the questionnaire. Statements which do not prompt a range of responses on the scale from strongly agree (1) to strongly disagree (5) have little benefit as discriminatory items on the questionnaire. Therefore, two types of items were identified; those with means that were 'too low', ie most people agreed with, and those with means 'too high' that most people disagreed with. On this basis the questionnaire statements can be rephrased so that the statement is more likely to elicit a broader range of responses

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and therefore provide more useful data.

The statements which were found to elicit too much agreement were identified from the means and standard deviations and were rephrased in such a way as to make them more difficult to agree with, being 'stronger' in their content. These statements are listed in Table II along with their revised versions.

A set of statements were also identified which the participants found too easy to disagree with. These statements were 'toned down' so that it would be more likely to elicit a broader range of responses from the participants

Table II

C4	The group allowed me to express my views
	The group allowed me to express all of my views.
C6	Opinions were generally addressed through the leader
	Opinions were addressed through the leader
Ch6	The group worked together efficiently
	The group worked together very efficiently
Ch5	I liked working with this group
	I really liked working with this group
C3	My views were represented in the decision
	All of my views were represented in the decision
I2	I enjoyed the group discussion
	I enjoyed the group discussion very much
I4	People got quite personally involved in the decision
	People got personally involved in the decision
P4	Evaluation of the solutions was done in a systematic way.
	Evaluation of the solutions was done in a very systematic way.
F4	The discussion was focused around the problem in hand
	The discussion was focused on the problem in hand.
I5	The task was taken seriously
	Everyone took the task seriously
P8	The acceptability of each solution was discussed
	The acceptability of each of the possible solutions was discussed

Table II Rephrased Questionnaire items which produced 'too much' agreement.

Table III

My ideas were not taken into consideration in the final decision.
Some of my ideas were not taken into consideration in the final decision.

I found it difficult to get my views heard
I found it quite difficult to get my views heard

There were many disagreements between the group members
There were several disagreements between the group members

This group does not work well together
This group does not work as well together as it could.

Conflict existed between some members of the group
Some conflict existed between the members of the group

The discussion lacked structure or direction
The discussion could have had better structure or direction

We did not have enough time to make the decision
We did not have enough time to make the decision as well as we could have done

Table III Rephrased Questionnaire items which produced 'too much' disagreement.

3.4 Multivariate Analysis of Questionnaire Items

3.4.1 Smallest Space Analysis

In order to assess the relationship between the questionnaire items the participants' responses to the questionnaire were analysed using Smallest Space Analysis (SSA-1). This analysis will reveal whether the items which have been hypothesised to relate to each of the task and group process domains are associated with one another, and therefore whether they act as measurements within the same fields.

Smallest Space Analysis begins with a matrix of associations between items being analysed. From this a geometric representation of the relationships between the items as points in Euclidean space is given. The distances between the points in the space are the inverse of the rank order of correlations between the variables, thus the higher the correlation between the questionnaire items the closer together they will be plotted in the space.

The two sets of questionnaire items will be analysed separately, those relating to group processes (communication, cohesion, and leadership) and those relating to the task (task, task focus and problem solving). According to the Principle of Contiguity (Foa 1958) items which are drawn from the same conceptual domains will be plotted in such a way that clear regions can be established in the plot relating to each of hypothesised areas. In the present analysis it is hypothesised that in the first SSA three regions will be identified, containing the questionnaire items relating to communication, cohesion, and leadership. In the second SSA plot it is also hypothesised that three regions will be found, containing items hypothesised to

measure the ease of the task, the task focus and the problem solving strategies.

3.4.2 Group Processes

The participants' responses to the questionnaire items hypothesised to relate to communication, group cohesion, and leadership were analysed using SSA, and plotted in three dimensional space. Those items which were phrased negatively, for reliability checks, were reversed in the data matrix so that all the items within each of the group processes would be positively correlated if they were all measurements within the same domain. A two dimensional view of the three dimensional solution is presented in Figure 1.

Figure 1 demonstrates that three general regions can be identified, relating to each of the three group process domains. Items associated with the strength of leadership are located at the top right hand side of the plot ([]), those concerning group cohesion are found on the bottom right(O), and the items which assess the communication are at the bottom left (^). This analysis shows that generally the items associated with each domain are associated with one another and can be identified in three regions.

However, there are a few points which are not associated with the hypothesised measurement domains, and these are the points which need clarification in order to successfully develop the questionnaire.

i) Cohesion

Examination of the region of the SSA plot associated with group cohesion demonstrates that there are two points which were not hypothesised to be associated with these items.
The statement 'The discussion lacked structure or direction' (L3) was hypothesised to be a leadership issue, but is not located in the leadership region. Examination of the original correlation matrix shows this item to be highly correlated with the Focus statements. This item is thus more accurately a measure of the task focus rather than an implication of the lack of leadership in the group. For this reason this item was kept in the questionnaire, but redefined as to the area of its content.

Similarly, the item C7, 'I didn't understand some of the directions being taken', is also 'misplaced'. It was hypothesised that this question would indicate poor communication, but again by referring to the correlation matrix, it is possible to discover that there is a high correlation between this statement and 'I understood the task clearly' (T2) indicates that it is a measure of the clarity of the decision problem. This item was also kept in the questionnaire but redefined.

It is also possible to draw conclusions about the items which were considered to be group cohesion items, but are not located in the 'cohesion' region. The statement 'Once people made up their minds they were reluctant to change them' (Ch1) is found at the top of the plot, not being very strongly related to any of the items. Indeed the correlations of this item with all of the other items are small, many being negative. This item is clearly not a
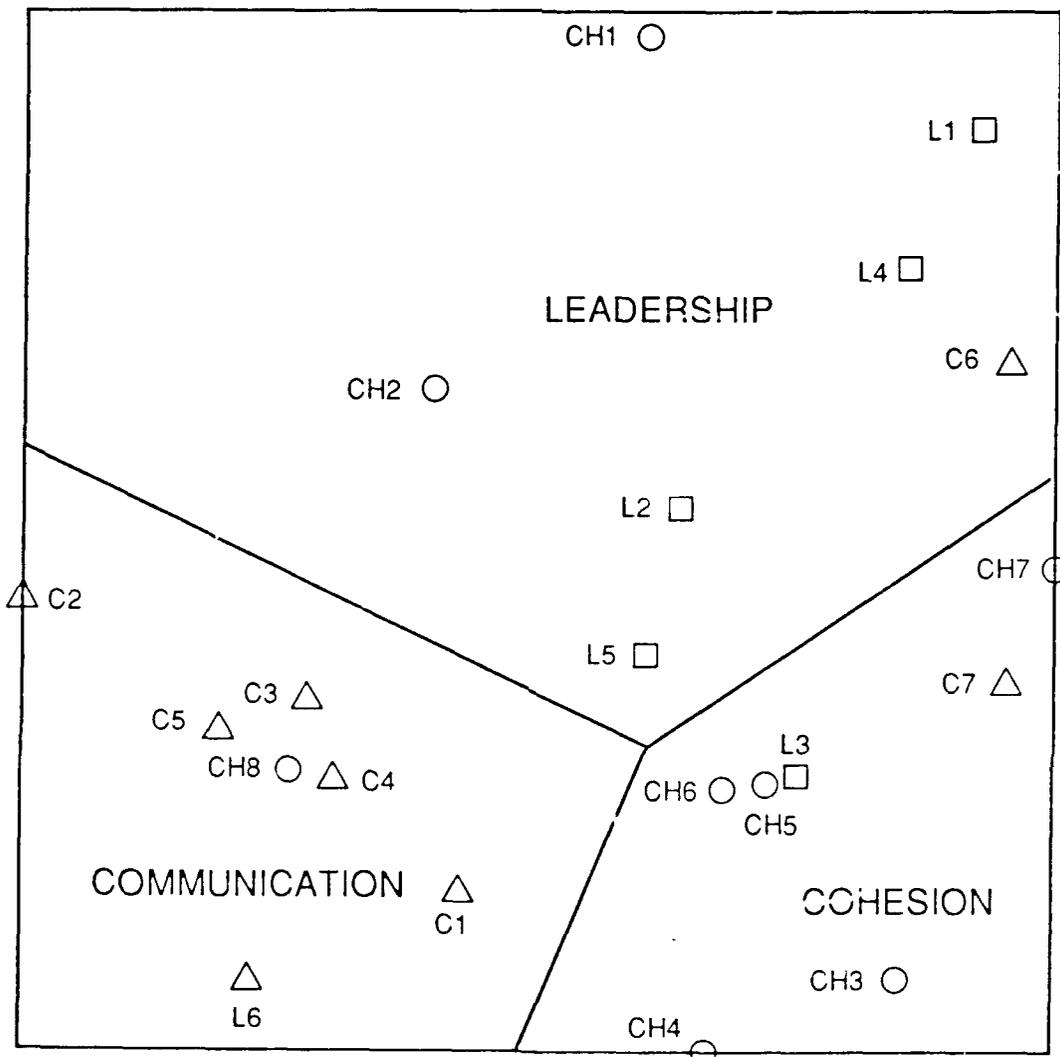
Figure 1. SSA Configuration of Twenty-One Statements Regarding Group
Processes from the Pilot Questionnaire, Derived from Thirty-Seven Respondents'
Ratings of their Decision Making Group.

Vectors one by two of the three dimensional solution are presented. The Co-
efficient of Alienation is 0.137.

useful measure of anything and was excluded from the questionnaire.

Similarly, 'I made some compromised for the group' (Ch 2) is not placed in the appropriate region in the plot, and does not correlate well with the other cohesion items. This item was also removed from the questionnaire.

Interestingly, one further cohesion point is 'mis-placed', being located in the communication region of the plot. Item C8, 'I did not feel I was a part of the group', (recoded), is most highly associated with the communication points referring to being allowed to present one's views, and views being represented in the decision. This may be indicative of the fact that belonging to the group is indeed a function of the amount of 'say' the individual had in that discussion.

On the other hand, it is possible that this mis-positioning in the plot may be a function of the 'noise' created in the data from the points which are not adequately measuring the domains for which they are selected. Once the obvious problem items have been examined the data can be re-analysed, and the results will be discussed below.

ii) Communication and Leadership

One of the hypothesised communication items has already been discussed (C7), being redefined as a task measure. However, item C6, 'Opinions were generally addressed through the group leader' is also not located in the communication region. This point is located the leadership region and is clearly less to do with communication structure as with the way in which the group was run in terms of leadership. This point was kept in the questionnaire, but redefined accordingly.

Similarly, the item 'Certain individuals dominated the discussion' (L6) was hypothesised to be a measure of the way the group was led. Its position in the communication region suggests that it is rather a measure of unequal communication. This point was redefined and kept in the questionnaire.

3.4.3 Ambiguities

Finally it is worth noting that the regions have been drawn on the plot on the basis of the hypotheses made regarding the three domains of measurement. Examination of those points which were clearly mis-placed has allowed the further development of the questionnaire. However, there are a number of points which fall on the borderlines of the regions and could be legitimately be considered to belong to the neighbouring region. For example, item Ch7, 'This group does not work well together' (recoded), could conceivably be considered a leadership problem. Similarly, 'The leader encouraged me to express my opinions' (L5) is close to the communication region, and could be considered a communication issue.

These ambiguities are of great : crest in themselves. The 'grey areas' between regions are to be expected and add further weight to the relationship between the areas as elements of the facet of 'Group Processes'. This analysis reveals that the three processes identified are all important aspects of group decision making and form a model of the pertinent variables in group decision making.

Further analysis of this data in future research will allow some valuable insights into the nature of group decision making itself, as well as laying the foundations for assessment of the feedback system for group decision making being developed.

3.4.4 Reanalysis

Reanalysis of this data without the two items which have been excluded, and the two points redefined as 'ease of task' and 'task focus' demonstrates that items which measure each of the three group process dimensions can be found in three distinct regions in the SSA plot (Figure 2). The only item for which ambiguity remains is the cohesion item, 'I did not feel I was a part of the group', (Ch8) which remains more highly associated with communication issues than with group cohesion. This item was removed from the questionnaire.

These findings therefore illustrate that the questionnaire provides a reliable measure of the group members' perceptions of these three processes in group decision making. These measures can therefore be used for the ongoing research in order to model perceptions of group processes in decision making, which will provide a valuable addition to the development of the inference derivation system for group decision making.

3.4.5 Task Variables

The questionnaire items which were hypothesised to be related to the task (T), the task focus (F) and the problem solving strategies (P) were also analysed using SSA.

The two dimensional representation of the SSA solution is shown in Figure 3. In the same way as the group process variables, the task variables fall into three broad regions according to their hypothesised area of measurement, and once more recommendations for the restructuring of the questionnaire items can be given.

However, it is interesting to note that the task variables partition the plot differently to the group process variables. Whilst the group process variables formed a 'polarising' facet, being categorical in nature, the task variables are simply ordered from items referring to the task itself, to the groups' focus on the task, to the way that the task was solved (problem solving).

i) The Task and Problem Solving

All of the hypothesised items relating to the task itself are to be found in the same region of the plot, indicating that they are highly related. However, it is interesting that one of the items believed to be a measure of the focus on the task, referring to the amount of time required to solve the task, makes more sense when seen as a variable of the task itself, ie that the actual task set was possible in the time. For this reason item F4 was redefined as a task item.

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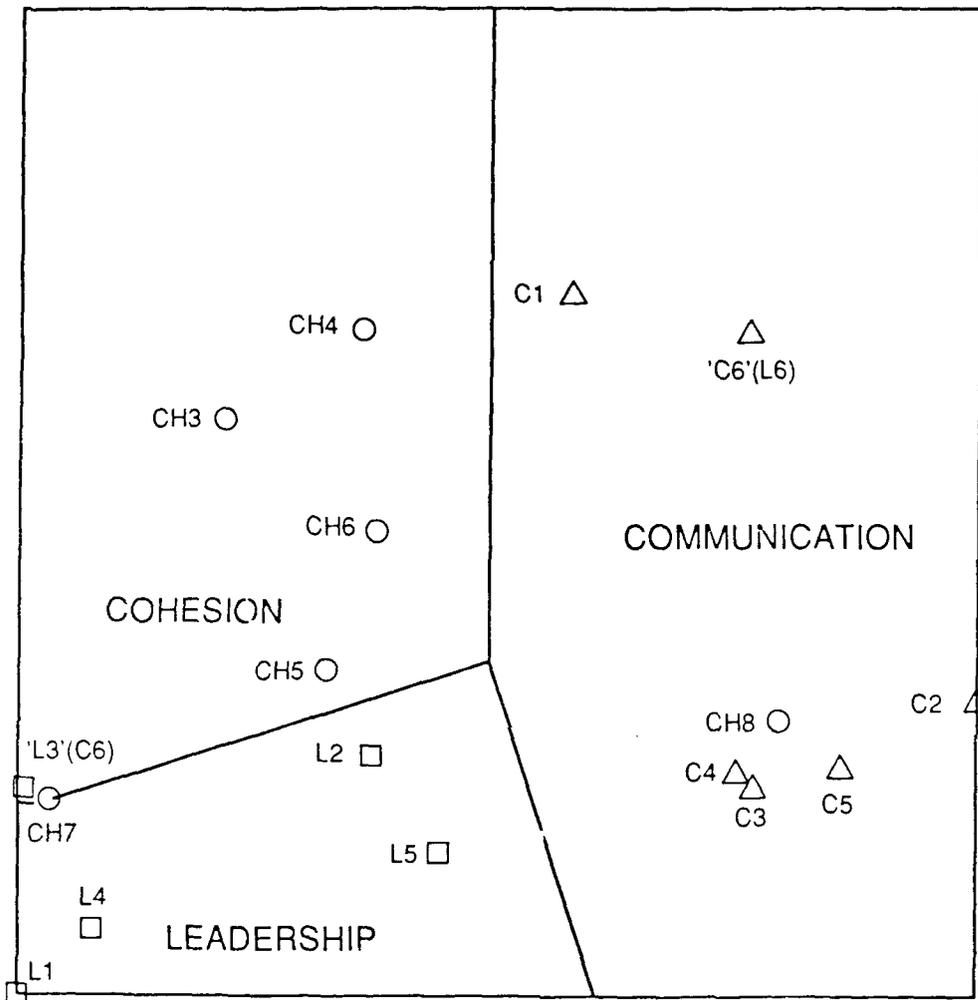
Figure 2. SSA Configuration of Seventeen Statements Regarding Group Processes from the Pilot Questionnaire, Derived from Thirty-Seven Respondents' Ratings of their Decision Making Group.

Vectors one by two of the three dimensional solution are presented. The Co-efficient of Alienation is 0.107.
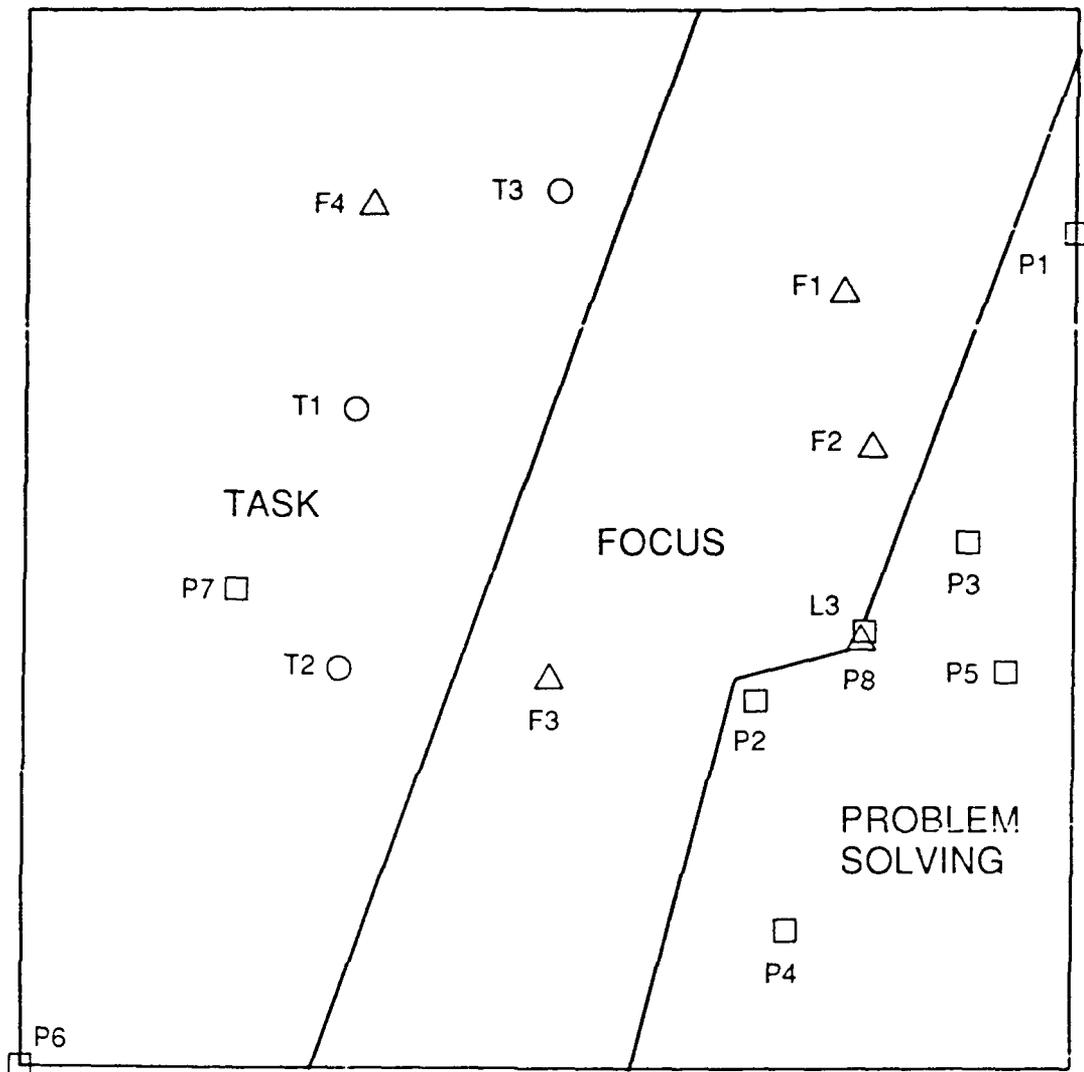
Figure 3. SSA Configuration of Sixteen Statements from the Pilot Questionnaire Regarding the Task, Derived from Thirty-Seven Respondents' Ratings of their Decision Making Group.

Vectors one by two of the three dimensional solution are presented. The Coefficient of Alienation is 0.141.

Other points which are 'mis-placed' in the task region, however, are not easily reinterpreted. Problem solving items, P6 'Rejected solutions were reconsidered towards the end' and P7, 'We narrowed down the solutions early on in the discussion' are found on the opposite side of the plot to the other problem solving items. These two items are rather ambiguous in their description of the problem solving strategies. Whilst the other problem solving items are seen to be positive, being essentially measures of good problem solving skills, items P6 and P7 may not be. If it was possible to define these two strategies as purely negative, then recoding of these items should allow the SSA to place them into the appropriate region of the plot. However, these items are not simply reversible. It is possible that narrowing down the solutions early could be considered a good strategy, as well as perhaps a bad one. Similarly, to reconsider rejected solutions may be 'thorough' in one sense, whereas it could also may be indicative of poor problem solving strategy, since good solutions would have been rejected at the start. Because of the confusion surrounding these items, they have both been excluded from the questionnaire.

Once the two items discussed above have been excluded from the questionnaire, the remainder of the problem solving items fall into a clear region on the right hand side of the plot, indicating that they are all associated with the groups' approach to solving the decision problem.

ii) Task Focus

The region in the centre of the plot contains those items which were hypothesised to relate to the decision makers' focus on the task itself. It has already been established that the proposed measure of focus which deals with the amount of time given to the task, is more readily interpreted as a measure of the ease of the task itself. The other three items are found in the 'focus' region along with the item F5 which was redefined as part of the domain of task focus as a result of the analysis of group processes discussion above.

3.4.6 Reanalysis

Reanalysis of the task variables on the basis of the SSA results reveals that there are three clear regions including items relating to the task itself, focus on the task, and the way in which it was solved. The revised SSA plot is shown in Figure 4.

3.4.7 Perceived Success

Having established that the questionnaire items are measuring the aspects of the decision making process for which they were designed, it is possible to examine the relationship between these domains and the participants' perceptions of the success of the decision.

Figures 5 and 6 show the SSA plots for the group process and task domains with the success items included in the analysis. These SSA's therefore give an indication of the relationship between the decision making variables and the group members' perceptions of the success of the decision.

Figure 5 shows that the two items relating to the success of the decision are located in the

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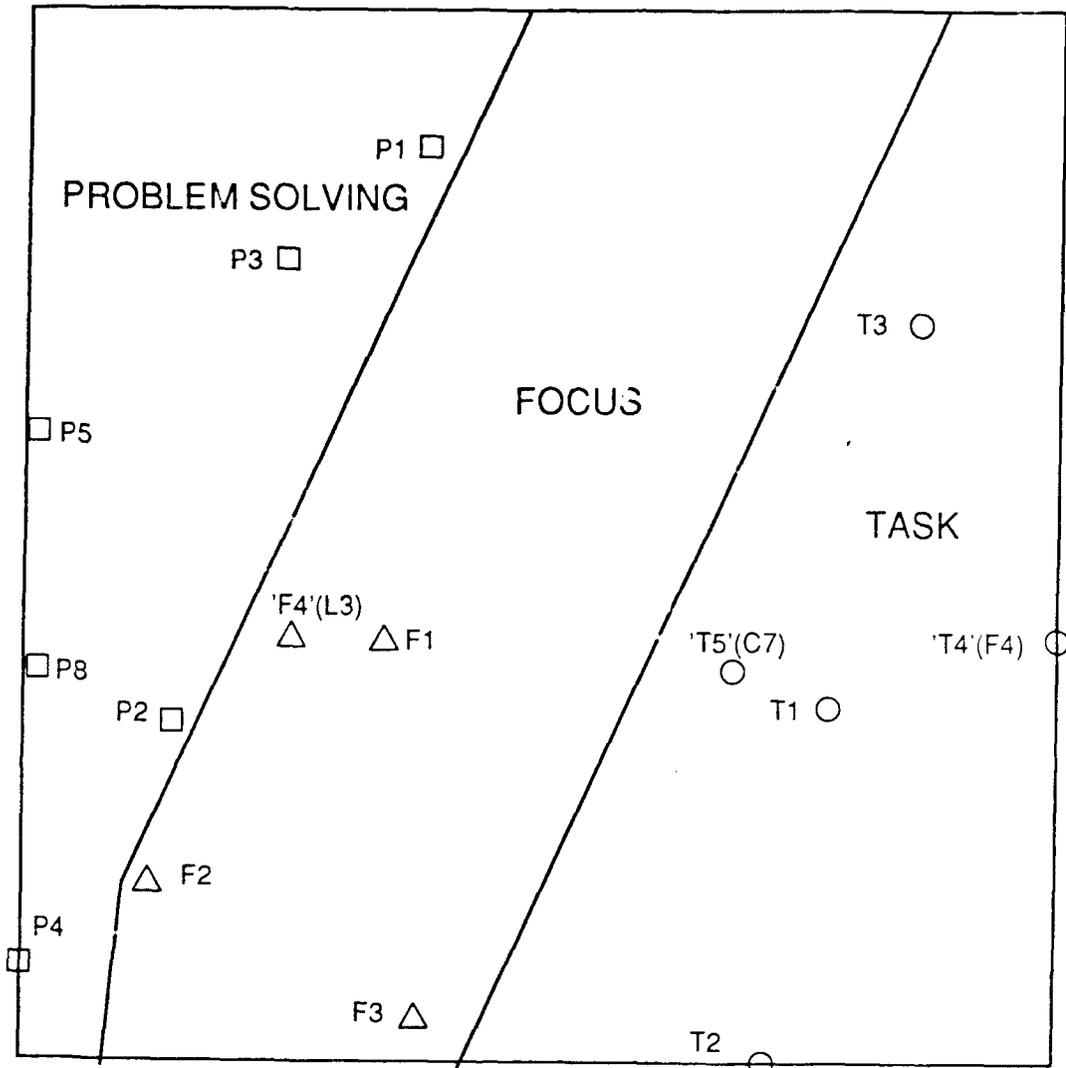
Figure 4. SSA Configuration of Fifteen Statements from the Pilot Questionnaire Regarding the Task, Derived from Thirty-Seven Respondents' Ratings of their Decision Making Group.

Vectors one by two of the three dimensional solution are presented. The Co-efficient of Alienation is 0.153.
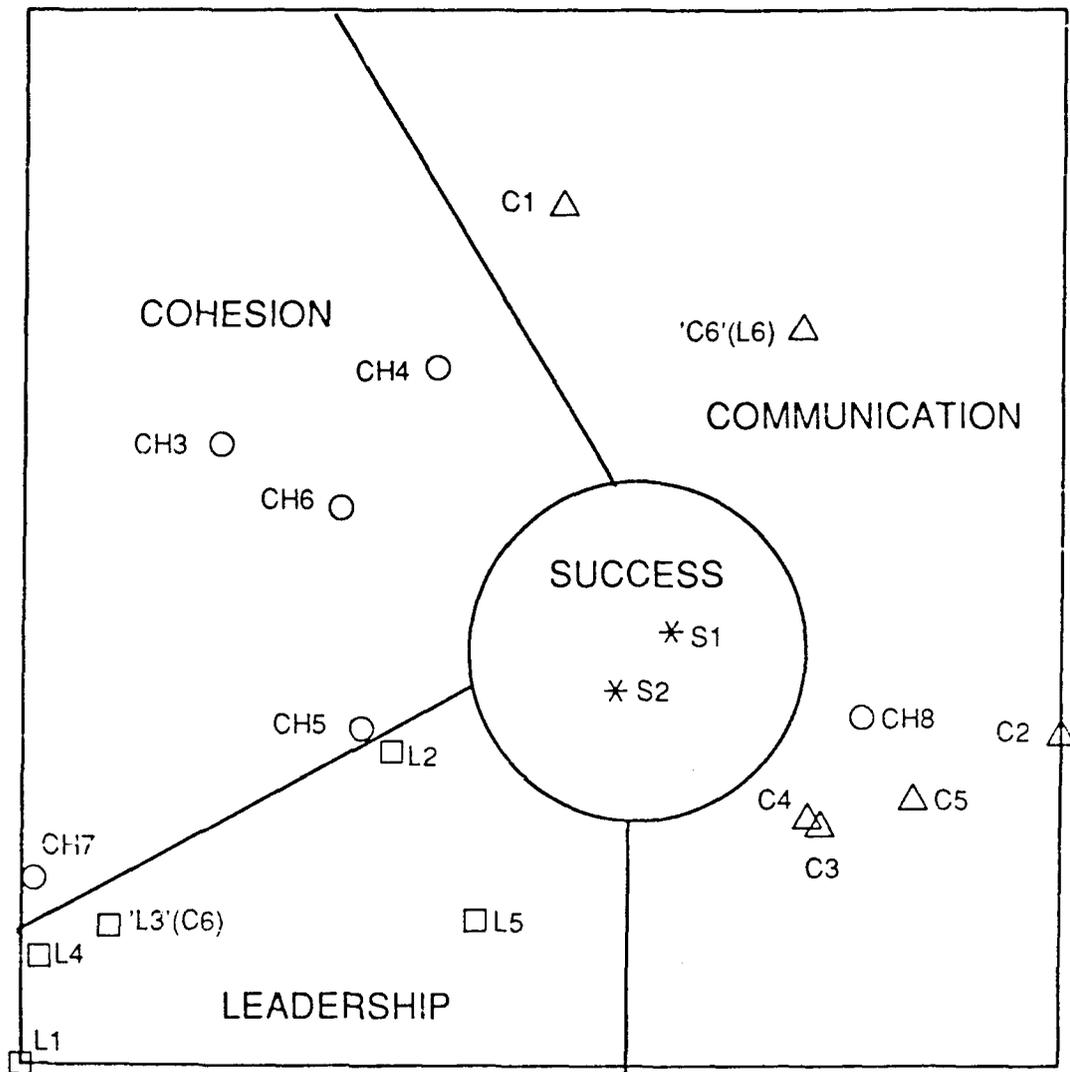
Figure 5. SSA Configuration of Nineteen Statements from the Pilot Questionnaire Regarding Group Processes and Success, Derived from Thirty-Seven Respondents' Ratings of their Decision Making Group.

Vectors one by two of the three dimensional solution are presented. The Coefficient of Alienation is 0.116.
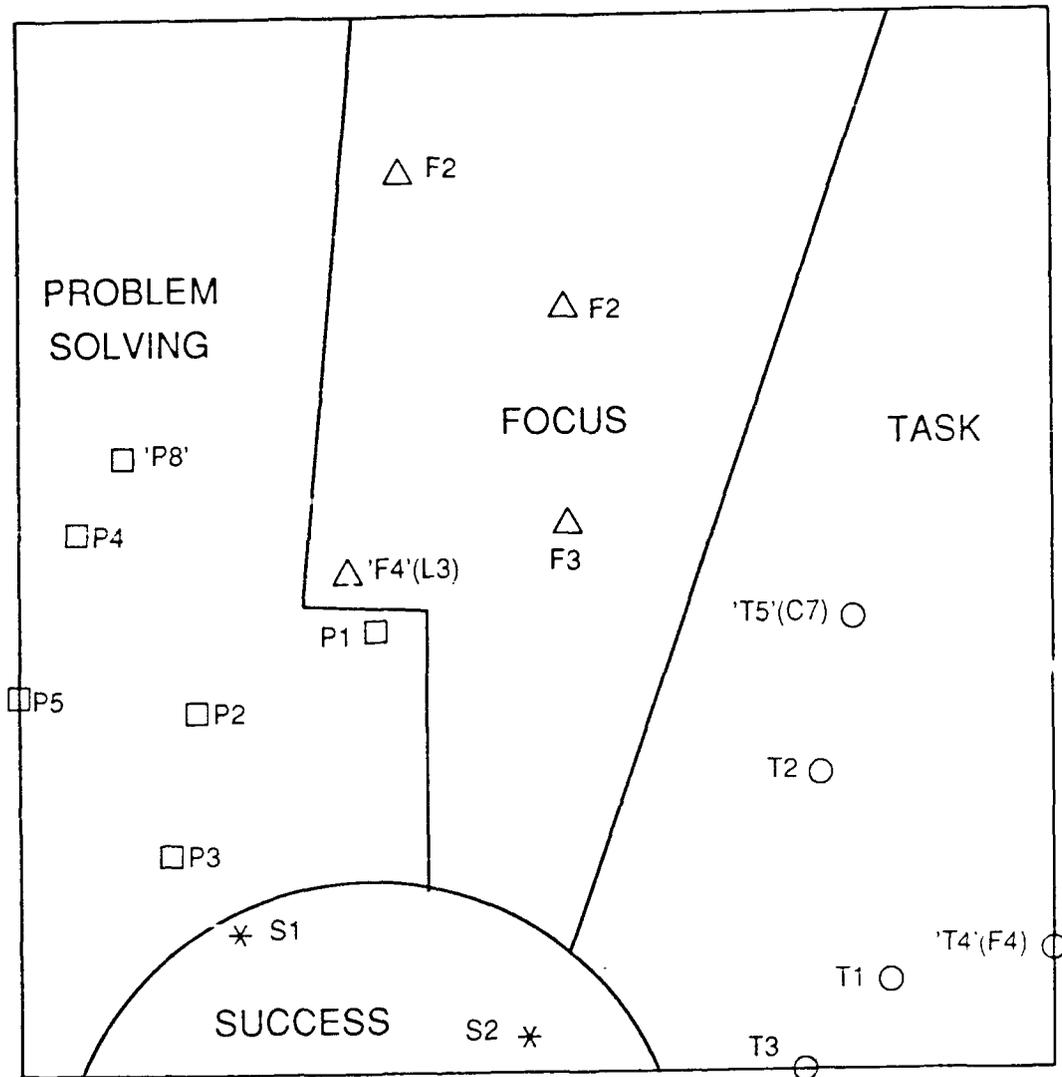
Figure 6. SSA Configuration of Seventeen Statements from the Pilot Questionnaire Regarding the Task and Success, Derived from Thirty-Seven Respondents' Ratings of their Decision Making Group.

Vectors one by two of the three dimensional solution are presented. The Coefficient of Alienation is 0.147.

centre of the plot. Since the group process variables form a 'polarising facet', ie the regions are arranged as segments around a common origin, then the location of the success items implies that all of these group processes are important to the perceived success of the decision.

Similarly, examination of the SSA plot for the task domains shows that the success items are located at the bottom centre of the plot. Since the task items are related in a simple order, then this positioning of the success items indicates that perceived success is also related to the task dimensions which have been selected in the questionnaire.

Although this analysis has some interesting implications regarding the relationship between these processes, it too is based on the first pilot study, and further research is necessary in order to examine these findings more thoroughly.

Summary

Analysis of the pilot data has allowed the rephrasing of the questionnaire statements and the testing of hypothesised areas of measurement using SSA. The resulting thirty-eight items were used to construct a reliable questionnaire to measure the participants' subjective ratings of task and group processes.

CHAPTER FOUR:
MODELLING PERCEPTIONS OF GROUP DECISION MAKING. A PILOT STUDY.

The pilot questionnaire data is analysed using Partial Order Scalogram Analysis (POSA) to demonstrate how differences in people's experience of group decision making can be represented. An example is given to illustrate the differences in individual's perceptions of communication in their group, based on data collected from seven decision making groups. The results show that POSA models both the individuals' quantitative overall satisfaction with communication and the qualitative differences in their assessment of different communication issues.

The 'objective' MSA model of the individuals' input in two decision making groups is compared to the 'subjective' group members' perceptions of their communication modelled using POSA. Pilot results indicate the scope for linking the two objective and subjective modelling techniques.

CHAPTER FOUR:
Pilot Application of the Questionnaire Data

4.1 Modelling the Decision Process

The pilot research on the use of the inference derivation system has been tested using Multidimensional Scalogram Analysis (MSA) presented to groups of volunteers working on the 'student housing problem'; a hypothetical decision situation requiring the choice of six properties suitable for student housing.

These preliminary experimental studies are necessary in order to investigate a number of dimensions of the group decision making process using a carefully controlled hypothetical decision making exercise, before moving on to examine more complex decision making groups such as those relating to the linking of serial crime.

Using this hypothetical problem it is possible to elicit information from the participants using the facetted sorting procedure, and to represent the group members' knowledge using MSA. These pilot studies have demonstrated that it is possible to represent both the task and the process aspects of group decision making and that feedback of these representations holds considerable potential as a system for decision support.

Previous work has suggested that there are two qualities of the representations provided by MSA which contribute to its potential value as a decision aid. Firstly, it is possible to provide a spatial representation of a number of decision options with respect to the similarities and differences between them on a number of dimensions relevant to the decision. It hypothesised that such representation of the options in a decision task, with respect to the variables which distinguish them, will be of value in solving a decision problem based on qualitative data.

Secondly, the representations used have the potential to allow comparison between the judgements made of each of the instances by each of the group members. The attributes which each individual judges to apply to each of the instances, or decision options can be mapped onto the plot and used as a system of feedback of group processes. Thus disagreements between group members can be identified, and decision options favoured by each member can be compared.

The actual details of the decision problem which the volunteers were presented with can be found in the Chapter Two. Two new groups are considered in the current chapter, drawn from a population of Metallurgy and Materials students in their first year at University.

Before the groups met to decide on their selection of properties, each individual member was introduced to the decision problem, their role in the group, and was asked to take part in a facetted sorting procedure for the elicitation of their 'knowledge' or opinions about the properties.

The MSA plots can therefore be used to demonstrate the opinions of all the group members as a composite. Thus those properties which are more similar according to the sorting criteria

will be found in the same regions of the plot. In this way, the previous work has demonstrated that a group who are working with the values expressed in the elicitation exercise will chose properties which are closer together in the plot, being more similar in terms of the criteria thought to be important to the decision.

These MSA representations allow us not only to examine how 'coherent' the decision was, on the basis of the constructs used in the sorting task, but also the way that the plots maintain the individual contribution to the group knowledge allows the examination of the opinions of each individual member to be overlaid onto the plot revealing whose opinions were and were not included in the final decision. The MSA representations of the two new decision making groups are shown in Figures 1 and 2.

Figures 1 and 2 show these composite MSA plots summarising the decision problem as perceived by each of the two groups. The points in the space represent each of the decision options, in this case the properties. The structure of the task, as perceived by the group, is represented by the distances between the points, the more similar the properties according to that particular group's criteria, then the closer together the points will be. The properties which are circled are those which each group selected following the group discussion. Therefore the closer together the properties selected the more similar they are on the dimensions judged to be important by the members of the group. Finally each of the shaded area indicates each group members opinions of the properties before the meeting, with those properties falling in a shaded are being rejected by the individual according to the particular criteria they were dealing with. A fuller description of the interpretation of these plots is given in Section 4.4 with respect to their relationship to the questionnaire measures.

The present discussion of the modelling techniques considers two groups, one group using provided constructs, and one group using elicited constructs. The next stage of the research will consider more directly the stages in the decision making process in order to relate the modelling techniques to what actually happened in the groups. The present analysis aims to assess whether the objective view of what went on in the group decision making exercise (MSA plots) can be related to the subjective ratings of the communication structure made by the group members.

4.2 Further Development of the Modelling Techniques

The way in which such diagrams summarise the task and process aspects of the group decision making exercise has been discussed at some length, illustrating that they can be thought of as a summary of processes that went into making the decision, the relationship between the decision options and the actual solution chosen.

The task for future work is to fill in the background to these representations in two ways. Firstly it is necessary to examine what actually went on in the group by studying the transcripts of the discussion to see how certain decision criteria (facets)were dismissed and which were used by the group in order to make the decision. This will enable the representations to be compared to the decision making process in order to examine the extent to which the summaries do represent the groups decision making process.

The present analyses confronts the second aim of the research in this area. It is necessary to
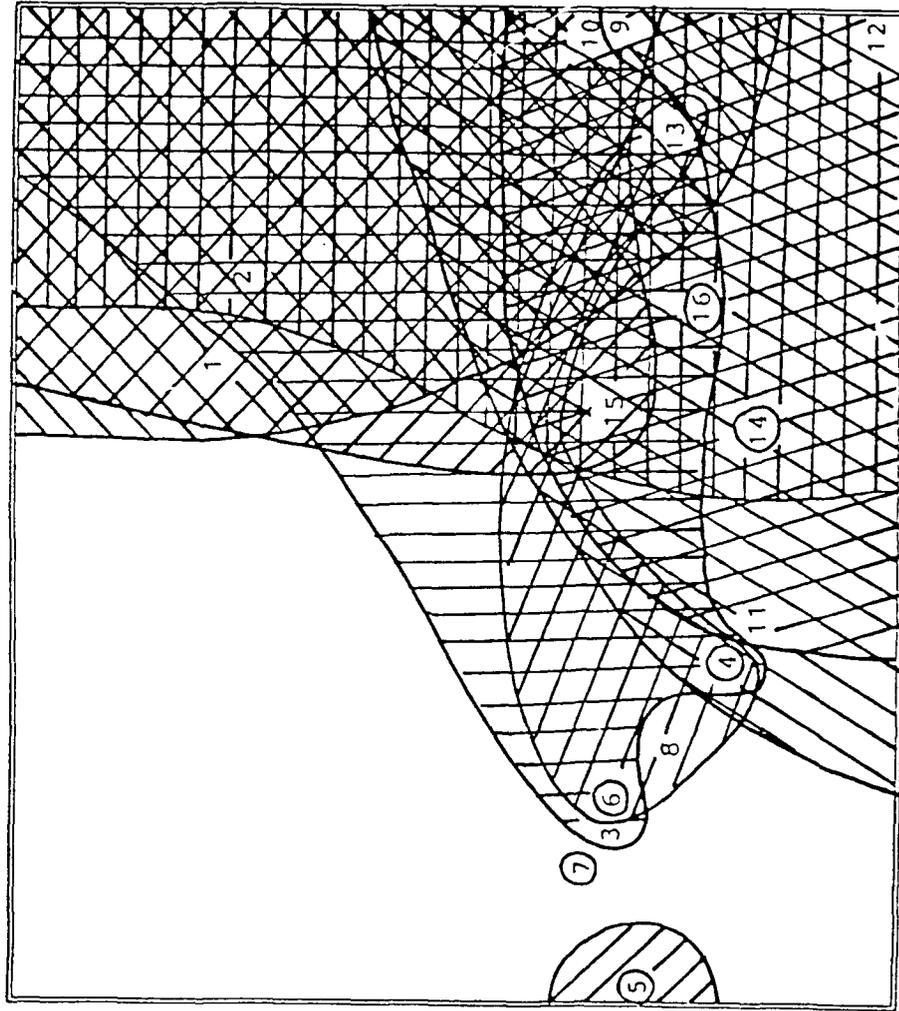
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Figure 1. MSA Plot of Student Housing Decision Problem for Group One
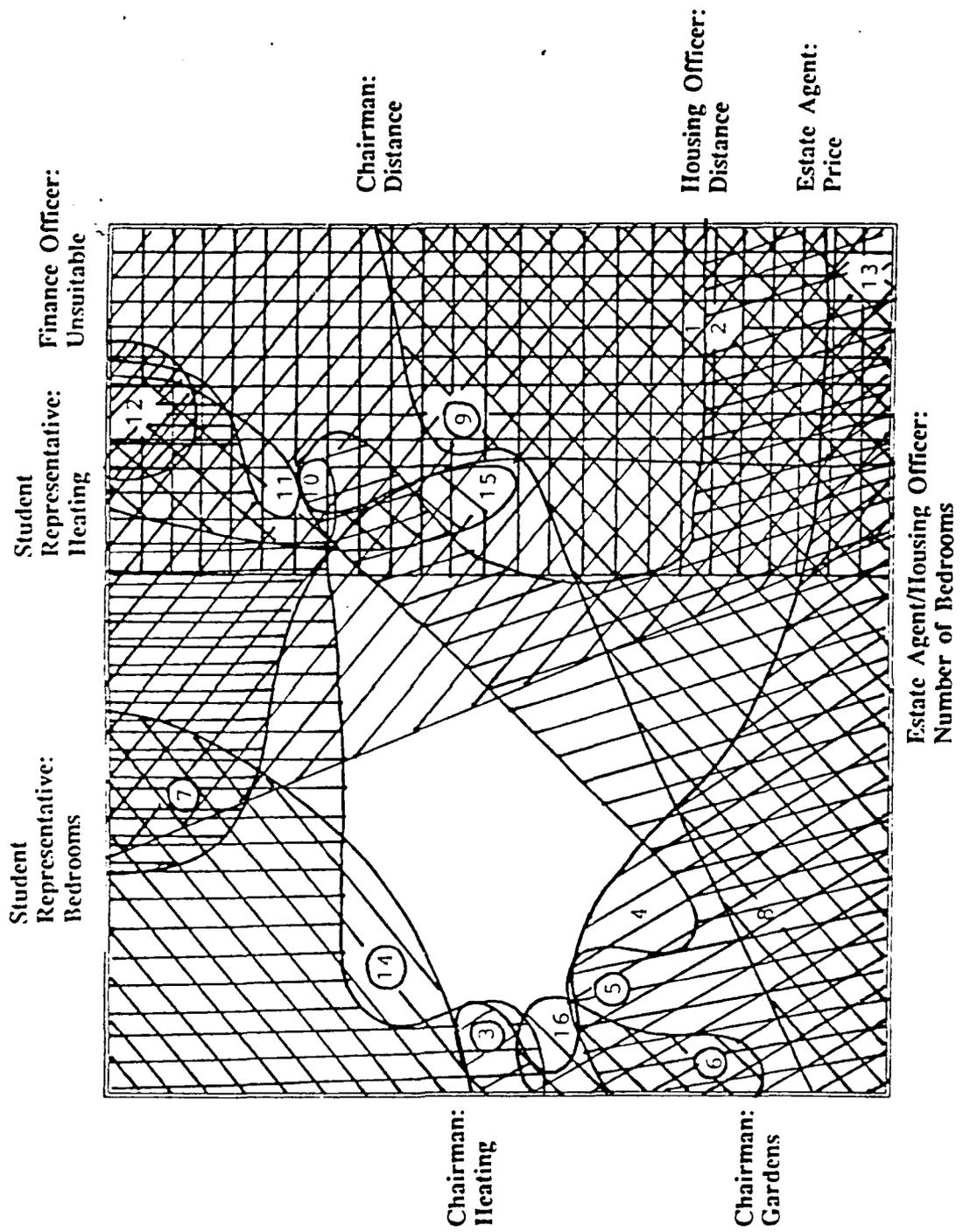
Figure 2. MSA Plot of Student Housing Decision Problem for Group Two

examine the participants' perceptions of the decision making group in order to assess the whether the objective summaries of the group's decision making compare to the participants' subjective experience of it. For example, the shaded areas in the MSA plots demonstrate each group member's opinion of the properties which are unsuitable for selection. Comparison of these areas with the actual selection shows those members of the group whose views were overruled in the decision making process. By developing the instrument to assess the participants' own rating of the group experience, it will be possible to examine whether these objective predictions are matched by the group members' perceptions.

Whilst this area of the research is currently being developed it is possible to present one example of this direction, in order to demonstrate the feasibility of this line of research. The example given relates to the six questionnaire items which were designed to assess the participants' satisfaction with a variety of communication issues. By analysing this data using POSA it is possible to compare the participants' feelings about the decision group with one another, so that their relative satisfaction with communication can be assessed.

4.3 The Evaluation of Group Communication: Using the Questionnaire Data

4.3.1 Introduction

On the basis of the findings described in Chapter Three of this report, one of the domains has been selected for a preliminary demonstration of the way in which the questionnaire data can be used to compare decision making groups with one another; i.e. communication.

The use of POSA is discussed, with respect to communication, defined by the participants' responses to six key items within the domain. In this way it is possible to compare the participants in each of the seven group investigated so far and to establish the members' perceptions of the communication within the group. This pilot work will establish procedures for comparison of the participants' subjective evaluations of the group, with the objective modelling techniques described in Chapter Two.

Therefore the following examples are presented in order to test the potential of these analysis procedures for investigating the group dynamics which is necessary for both the test and the development of the inference derivation system.

4.3.2 The Communication Items

Six variables were selected from the questionnaire as being measures of the communication processes within the group, derived from the SSA plots discussed in Chapter Three. The items selected were; 'My views were represented in the final decision', 'everyone's opinions were given an equal hearing', 'The group allowed me to express my views', 'I found it difficult to get my views heard', 'My ideas were not taken into consideration in the final decision', and 'Certain individuals dominated the discussion'. The scores for the last three of these items were reversed so that the responses could be scaled in the same direction. This essentially means that in the analysis rather than disagreement with the negative statement, agreement

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is shown with the reverse meaning of the statement. For example disagreement with the statement 'I found it difficult to get my views heard' is converted to agreement with the statement 'I did not find it difficult to get mt views heard'.

If each of these statements is treated as a variable for the analysis, the each person who filled in a questionnaire can be represented as a profile of scores across these variables, ranging from strongly agree (1) along a five point scale to strongly disagree (5). All thirty seven people who had filled in the pilot questionnaire were included form the seven hypothetical decision making groups studied so far.

The data matrix is thus

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        C1  C2  C3  C4  C5  C6  C7

P1   1   3   4   5   2   1   2
P2
P37
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One of the participants data was excluded from the analysis since there was missing data for one of the variables, leaving thirty-six different rows.

In this way each person can be represented by a profile of scores on each of the communication items representing their evaluation of the communication processes within their particular decision making group.

4.3.3 Partial Order Scalogram Analysis

The participants' profiles were analysed using Partial Order Scalogram Analysis (POSA). POSA provides a representation of the data in two dimensional space so that both the quantitative (level of satisfaction with communication) and qualitative (different aspects of the communication) factors of the data can be analysed. The level of their satisfaction is derived from the total of the scores across the profile, and the profiles are positioned as points relative to the x+y dimension. If the participants' profiles varied simply on a quantitative dimension to POSA would plot the points solely along the x+y dimension as shown in Figure 3a. However, POSA allows the analysis of qualitatively different aspects of the communication, for example, a profile score of 121211 would represent the same level of satisfaction (=8) as 122111, yet would be qualitatively different in its content with respect to the communication issues being considered. The qualitative differences between the profiles are represented across the x-y dimension. Each point in the space represents a profile of scores, which may apply to one or more of the participants. Participants who vary only in terms of qualitative differences would be represented along the x-y dimension as in Figure 3b.
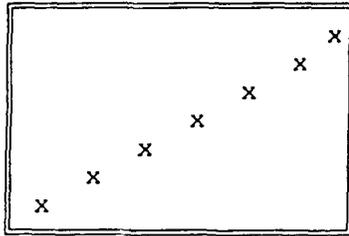
Figure 3a
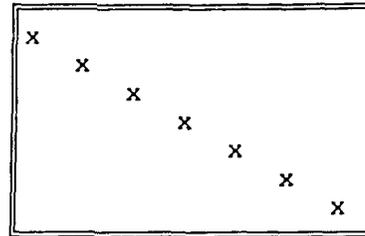
Figure 3b

Figure 3. Sketch Diagrams of the Quantitative and Qualitative Dimensions of POSA.

4.3.4 Results

The plots for each of the communication items analysed using POSA are shown in Figures 4a to 4f. Each point represents a profile of scores on the communication items associated with one or more of the participants. The points represent all the participants who have filled in a questionnaire following the decision making groups. In this way it is possible to compare the participants' perceptions of the communication structure in each of the groups and relate these ratings back to the group decision making summary diagrams (MSA plots).

Firstly it is necessary to examine each of the item plots for the POSA to see exactly what dimensions exist in the plot and therefore the way in which a participant's position in the plot can be interpreted. The POSA presents an item plot which corresponds to each of the variables in the study, in this case one for each of the communication items on the questionnaire.

Each item plot shows the same configuration of points, except the computer labels each point according to its score on each variable. In this way it is possible to divide each of the item plots into regions according to the score which the person gave to that particular questionnaire statement. By partitioning the plots according to these scores, regions are created in which all the points scoring the same on that item are enclosed, and demonstrating the direction of the scaling of the points on each variable. Figures 4a to 4f are partitioned according to the actual regions, shown in dotted lines, and schematically, in bold lines.

It is important to note that those questions which were negative in their content have been reversed so that all the items are scored in a comparable way. Therefore if someone was to strongly agree with the statement 'my ideas were not taken into consideration', by recoding it they would be strongly agreeing with the reverse of that, ie my ideas were (not) not taken into consideration'.

The first plot shows the partitioning of the question 'I found it difficult to get my views heard' (Figure 4a). This plot shows that the further toward the bottom of the plot along the y axis that a point is, the more likely that person is to have responded negatively, ie thought that it was easy to get their views heard. On the other hand Figure 4b shows that the plot can be divided along the x axis for the questionnaire item 'Everyone's opinions were given an equal hearing'. In this case the further a point is toward the left hand side of the plot, then the more likely that person is to have been positive about the equality of the representation
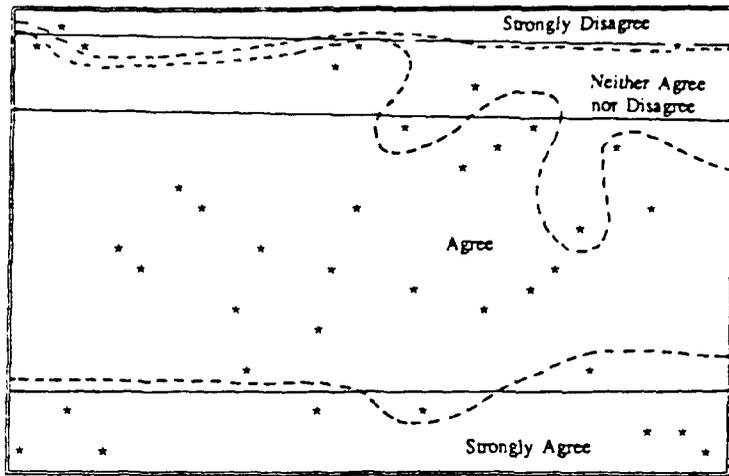
Figure 4a. 'I found it (difficult) easy to get my views heard.'
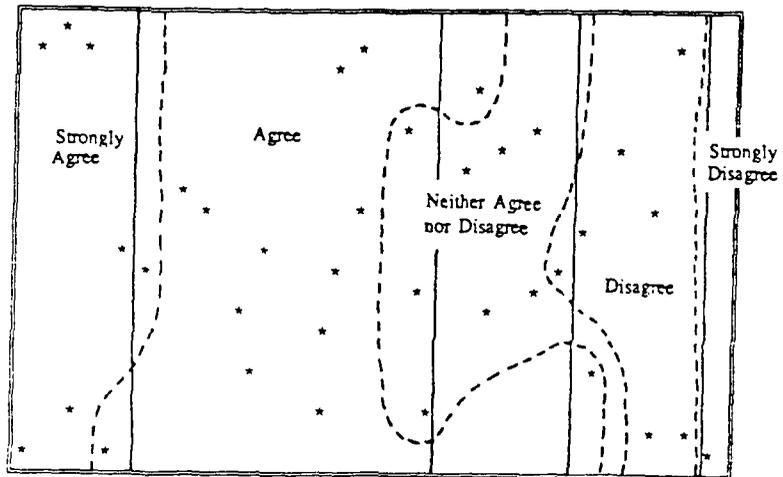
Figure 4b. 'Everyone's opinions were given an equal hearing'
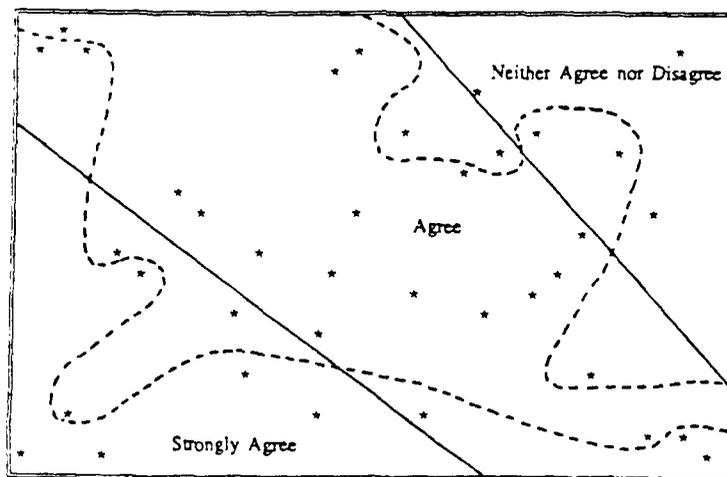
Figure 4c. 'My views were represented in the final decision'

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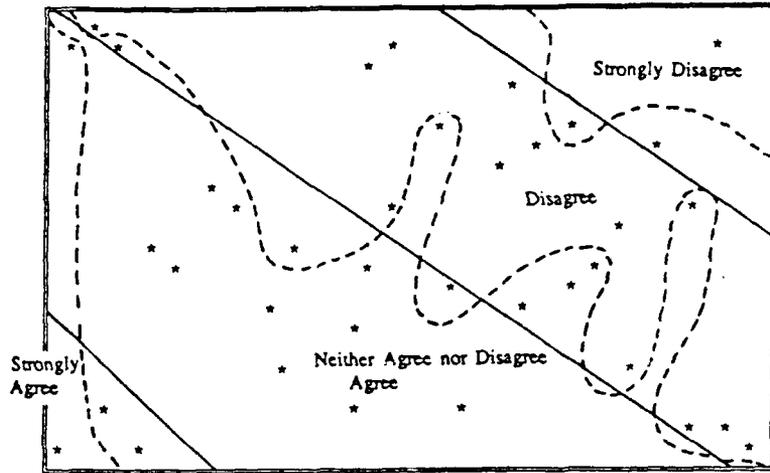
Figure 4d. 'Certain individuals (dominated) did not dominate the discussion'
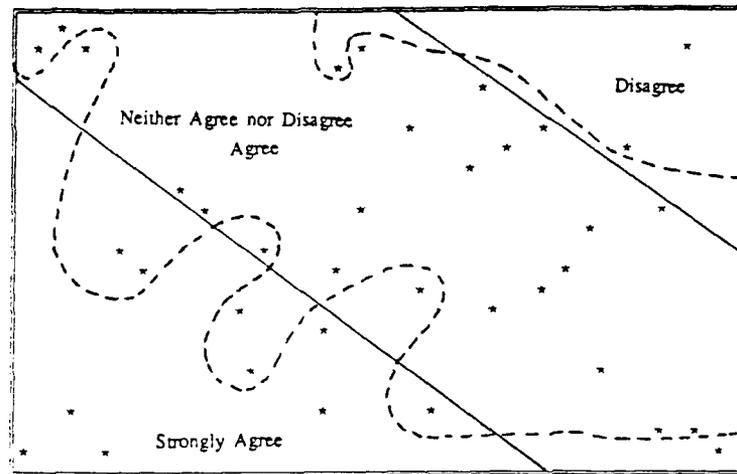
Figure 4e. 'My ideas were (not) taken into consideration.'
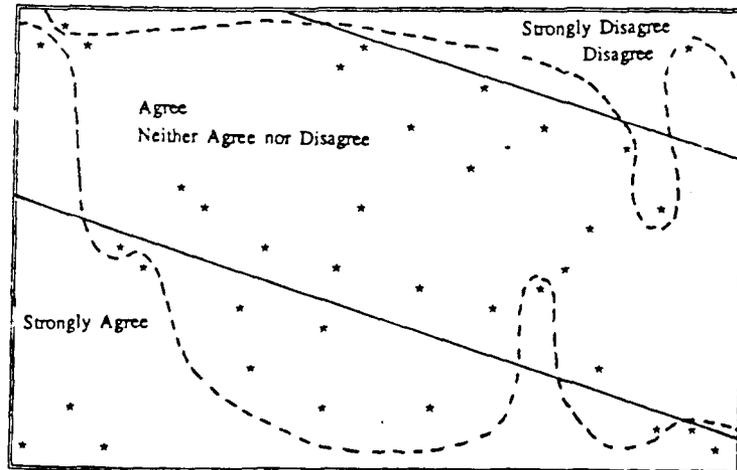
Figure 4f. 'The group allowed me to express my views'

in the group decision making.

The remainder of the plots can be divided according to the joint or x+y axis. Thus the closer to the bottom left hand side of the plot a participant is plotted, the more they are likely to think that their views were represented in the decision (Figure 4c), that the discussion was not dominated by certain individuals (Figure 4d) that their ideas were taken into consideration (Figure 4e) and that the group allowed then to express their views (Figure 4f). Figure 5 summarises this information.

4.4 The Relationship between MSA and POSA

Taking the overall POSA plot and the dimensions which distinguish between the individuals' perceptions of the group, it is possible to identify the position of the members of each of the groups. Thus it is possible to explore whether there is any relationship between the modelling of the group as an objective summary of the group decision making exercise and the opinions of the group members regarding the communication issues. Figures 6b and 7b show the members of the two new groups labelled on the plot. The relationship between the communication POSA and the MSA modelling is discussed in the following sections.

Group One

Figure 6a shows the MSA plot of the facetted sorts done by all of the members of Group One. The participants in this decision making group were given a sorting task before the group discussion using provided constructs. Earlier work has suggested that the MSA may not model a group decision based on provided criteria as well as those using elicited criteria for their decision. The properties eventually chosen by the group are circled in the diagram. In common with the examples given in the last report, the participants using provided sorts in this example did not chose properties which are 'coherent' in the plot, ie the properties are not grouped together in the plot, but rather spread across the bottom of it.

The partitioning shows the shaded regions of properties which were thought to be unsuitable by each of the group members, and thus more shading around a selected property indicates that more people did not recommend that choice.

Group One consisted of four members, the Housing Officer, Estate Agent, Maintenance Officer and Chairman. Examination of the shaded regions demonstrates the way in which the group members' views contributed to the eventual selection of properties. Figure 6a shows that property '7' was not excluded by anyone, and was indeed chosen. Property '5' was only excluded by the housing officer as having poor heating. Whilst properties '3' and '8' were only deemed unsuitable by one member of the group, (shown in one shaded area), they were not selected. Property '6' was thought to inappropriate by both the Housing Officer, on the grounds of its neighbourhood, and by the Chairman on the grounds of poor value. Property '4' was also excluded on these criteria, in addition to being thought of as a bad risk in terms of maintenance by the Maintenance Officer.

The Housing Officer was again overruled on the selection of property number '16', which he believed to also to be in an unsuitable neighbourhood. Further '16', had been rejected by the Estate Agent as being too far away from the University, and by the Maintenance Officer as

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Easy to be heard

Everyone's opinions equal hearing

Discussion was not dominated
Views were represented
Ideas were taken into consideration
Allowed to express my views

Figure 5. Summary Diagram of the Order of the Communication Items in the POSA Plot.
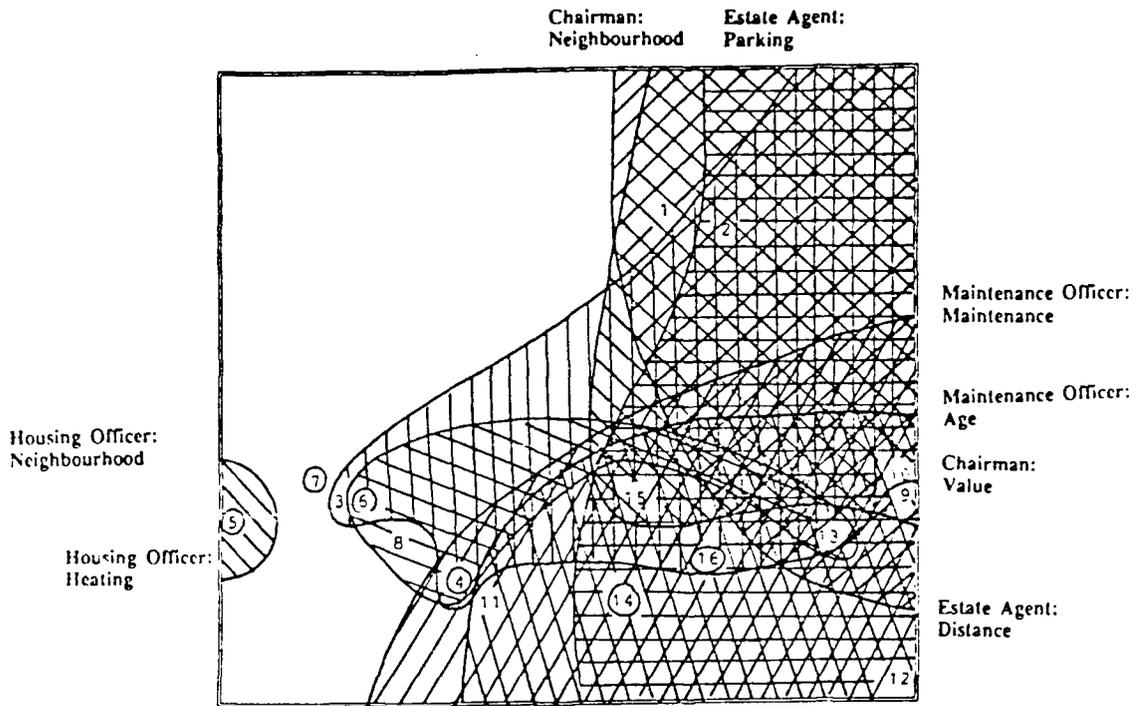
Figure 6a. MSA Plot of Student Housing Decision Problem for Group One.
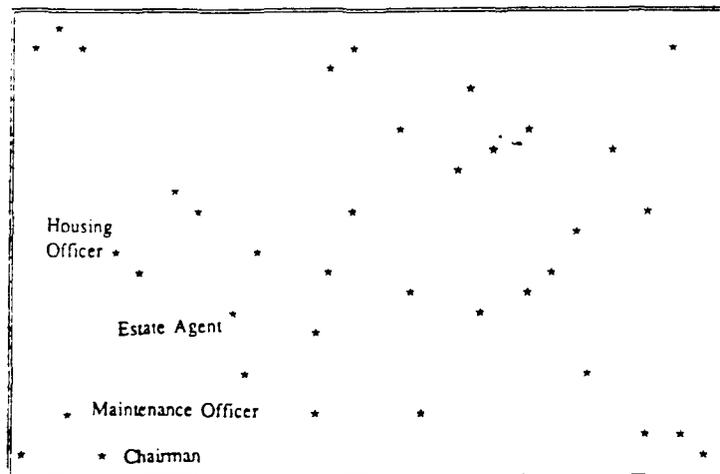
Figure 6b. POSA Plot of all Participants in the Student Housing Decisions with Respect to their Evaluation of the Communication. Members of Group One are Marked on the Plot.
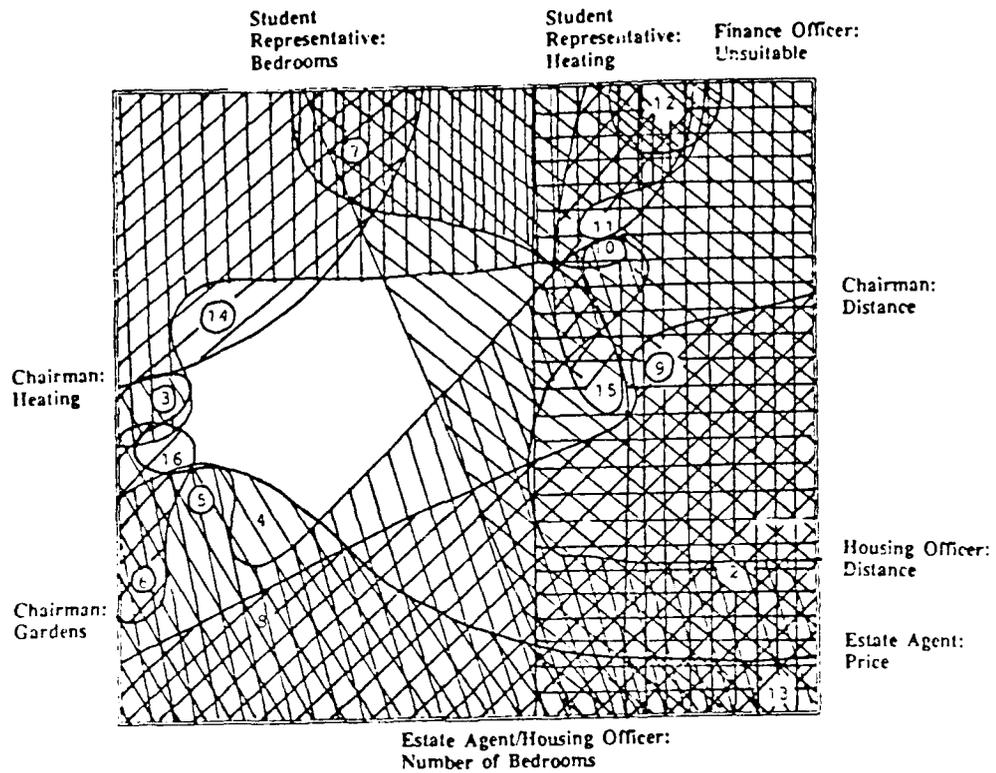
Figure 7a. MSA Plot of Student Housing Decision Problem for Group Two.
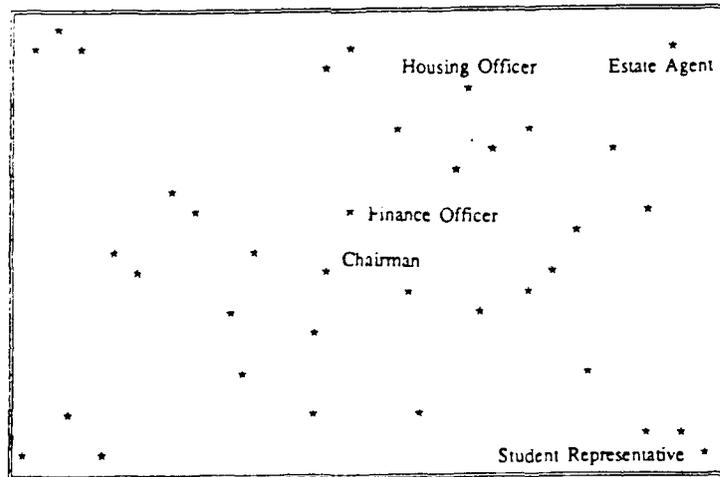
Figure 7b. POSA Plot of all Participants in the Student Housing Decisions with Respect to their Evaluation of the Communication. Members of Group Two are Marked on the Plot.

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being too old, and a bad risk for maintenance.

The properties chosen, along with the members of the group who were initially opposed to them, are summarised in Table I.

Table I

Role	5	7	6	4	16	14
Ch			*	*		
EA						*
MO				*		*
HO	*		*	*	*	

Table I Properties chosen which were excluded by each of the participants in Group One.

Once the 'objective' representation of individual group members' contribution to the decision solution has been considered, it is possible to compare the findings to the
POSA representations discussed above. By examining the 'subjective' ratings of communication made by the group members' it is possible to draw some tentative conclusions about the potential of these modelling techniques.

The position of each of the four members of Group One on the POSA plot for communication is shown in figure 6b. The most obvious conclusion that can be drawn from this plot is that all the members of Group One are extremely positive about the communication in the group. All four members of the group are positioned at the bottom left corner of the POSA plot, indicating that they all responded positively on the communication items.

Comparison with the objective modelling of their opinions of the properties indicates that all the group members made some compromises on their original views in order to reach a group decision. Nevertheless, the Housing Officer compromised on four of the six properties chosen, and can be seen to be the most negative of the group on the POSA dimension relating to how easy it was for his views to be heard. On the other hand, this participant was the among the most positive about the fact that everyone was given an equal hearing. In general, this group hold very similar opinions of the communication to one another, showing that the group as a whole were highly coherent in their perceptions of the experience, and very satisfied with the communication within their session.

This similarity of the perceptions of the group experience may be compared to the similarity between the group members in their opinions of the properties themselves, as revealed in the partitioning of the MSA plot (Figure 6a). Whilst there were properties which were eventually chosen although they were excluded by individuals, the plot demonstrates that overall the members of the group were working within a similar conceptual structuring of the properties. With the exception of the Housing Officer's opinion of property '5's heating, all the exclusion partitions are located on the right hand side of the plot, showing a broadly similar general

way of thinking about the properties' shortcomings.

Group Two

Previous research has suggested that groups using elicited constructs can be more successfully modelled than those using provided constructs. The MSA plot for Group Two, based on elicited sorting criteria is shown in Figure 7a.

Although this group used their own elicited criteria in the facetted sorting procedure the properties selected (circled) are not coherently placed in the MSA plot.

The lack of coherence in both the provided and elicited examples given here, illustrates the importance of developing the research to account for the actual decision making process. It is necessary to examine how the facets are actually used to come to a decision within the group, in order to account for the disparity between the view of individuals prior to the discussion and the selection made as a result of the groups' work.

It is essential to understand the mechanisms of this intervening process in order to develop all the stages of the system for modelling the dynamics of group decision making.

Examination of the partitioning in Figure 7a shows that none of the properties are positioned in unshaded areas, and most of the properties were thought unsuitable by at least two people. Only three of the properties ('16', '4' and '14') were ruled out by only one member of the group, and of these only '14' was chosen. This property was only excluded by the chairman on the grounds of inadequate heating. Property '3' was selected despite poor ratings from the finance officer and the estate agent. Similarly properties '5' and '6' were considered to be too far away by the Housing Officer, and to be too expensive by the Estate Agent. In addition property '6' was thought to have too large a garden by the Chairman. Property '7' was selected by the group despite being amongst those thought to be unsuitable by three of the five group members, and property '9' was originally excluded by all but the finance officer.

Table II

Role	3	5	6	14	7	9
Ch			*	*	*	*
FO	*				*	
EA	*	*	*			*
HO		*	*			*
SR					*	*

Table II Properties chosen which were excluded by each of the participants in Group Two.

Table II summarises the members of the group who did not recommend each of the properties which were eventually selected. The first conclusion that can be drawn from this data is that more of the participants had originally ruled out the properties eventually chosen than the members of Group One. Indeed, four out of five of the participants had excluded property '9', yet it was chosen in the solution. It is vital for future research to address the intervening stages in the decision making process in order to examine what exactly goes on in decision situation like this. For example, it is possible that it was the Finance Officer who persuaded the other members of the group to buy this house. Examination of the POSA plot in Figure 7b shows that along with the Chairman, the Finance Officer was indeed more satisfied with the communication of the group than were the other members.

The Estate Agent and the Chairman were 'over-ruled' on four out of the five properties, and therefore should be predicted to be the most dissatisfied with the representation of their views in the decision. Since earlier research has suggested that playing the role of chairman is particularly rewarding for participants, it is not altogether surprising that the chairman is quite positive about the communication of the group even though he has clearly made a number of compromises. However, the Estate Agent is found at the top right hand side of the plot, being the most critical of the communication structure of all the participants who have been involved in the research so far.

Looking at the distribution of the positions for the members of group two in the POSA plot illustrates that as a group they have a much less coherent view of the group experience in terms of communication. Whilst the members of Group One were all positive and positioned close to one another in the POSA plot, the members of Group Two have a variety of opinions of the communication in the group. The 'tight' configuration of the members of group one was compared to the coherence in the partitioning of the MSA space, indicating that they all had comparable types of conceptualisations of the decision problem. When this is compared to MSA pilot for the members of Group Two, it can be seen that the partitions are not centred around a common dimension, but are positioned around the MSA plot. It is possible then that the similarities and dissimilarities between the views of the members concerning the decision problem is echoed in the similarities and differences in their ratings of the group's communication structure. For example, the Estate Agent and the Housing Officer had exactly the same views of the properties in terms of the suitability of the bedrooms (right hand side of the plot), and that properties located around the bottom of the plot should be excluded. These two members were also overruled on the same three properties (5,6, and 9). Examination of the POSA plot shows that these two members of the decision making group are plotted on a similar dimension in the POSA. These results demonstrate the possibility of linking the two representational techniques, and suggest potential areas for development. The relationships discussed above are hypothesised links between the objective and subjective measures, and provide a starting point for further investigation of these issues in the inference derivation system.

Summary and Conclusions

Chapter Four has demonstrated the potential of the questionnaire data for modelling the participants' subjective experience of the decision making group.

The MSA plot allows an objective assessment of the group members' view of the properties prior to the meeting. Comparison of these views with the properties which were eventually chosen gives an indication of the extent to which ea¯h member's opinions were represented in the decision.
However, using the data collected from the pilot using the questionnaire it is possible to compare this objective modelling with the participant's own ratings of communication issues in the group.

Analysis of two groups using the hypothetical student housing problem demonstrates that it is possible to relate the group's cohesion in terms of their 'expert' opinions of the decision problem (MSA) to their perceptions of the group in terms of communication. These findings indicate fruitful directions for the expansion of the inference derivation system.

This analysis gives an indication of how representative the MSA plots are of the group decision, however, whilst it is hypothesised that individual perceptions will bear some relationship to the objective measures, there is considerable room for differences. For example, whilst a group member may have strong feelings about an issue prior to the meeting, the group discussion could change his or her view to the extent that they are happy to be overruled.

CHAPTER FIVE:
THE ROLE OF REPRESENTATION IN LINKING SERIAL CRIME. A PILOT STUDY.

The pilot study demonstrates the potential for representation using Multidimensional Scalogram Analysis (MSA) to structure qualitative differences between incidents of serious sexual attacks. Three experienced detectives took part in the study, and were asked to study ten victim statements in order to decide which of the incidents were linked, both individually and as a group. The statements were edited so that only information regarding the offenders' behaviour during the incidents was available.

Qualitative similarities and differences were elicited from the detectives and represented using MSA. The results show that using the police officers' own information MSA represents some of the true links between the incidents which they were unable to derive from their group discussion.

CHAPTER FIVE
Application to Making Inferences on Criminal Activity.

5.1 The data base.

The data base consists of detailed information about 62 serial offenders covering 200 different sexual attacks which has been established. Detailed statements are available for 200 attacks, that is full offense details on 27 attackers. This data base also includes 10 serial offenders who have murdered. All the attacks which have been compiled have been committed on strangers and they do not include victims who are known to the offender.

A selection of ten incidents were chosen from this data base for the decision making exercise.

5.2 Using MSA within a group decision making context.

It has been stressed that the inference system should be developed and tested within the context of a real life situation, and with application to criminal detection. It was therefore deemed of great importance to get a first pilot study using real police officers and real criminal incidents, in order to test the decision support system using the complex qualitative data found in witness statements and other police material.

A small group of police officers were therefore recruited to work on a simulated 'live' enquiry into a possible series of sexual attacks.

5.3 The Experts

The participants were three police officers (two detective inspectors and one detective constable) from the criminal intelligence office of a provincial police force. They have all worked both in the analysis of crime and as field officers. All group members have considerable CID experience, and in particular experience in identifying links within serial crime.

5.4 The Decision Problem

The police officers were presented with a set of ten witness statements of sexual attacks, 8 rapes and 2 sexual assaults. They were given no information about the geographic location of the incidents, the type of residence, or the offender description, all of which would normally be available to an enquiry. In order to set a limit to the exercise, the information they were given focused on the incidents leading up to the attack and the attack itself, focusing essentially on the behaviour of the offender.

The decision problem for the officers was to assess which of the incidents, in their opinion, were committed by which attacker. They were not told how many attackers were responsible, the task was to decide whether there was one or more attackers and which incidents were committed by which offender.

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Each person was asked to draw their own, individual inferences about the links between the attacks before the group meeting and independently of the other group members. They were asked to write down the variables which they considered distinguished between the attackers they had identified.

At the group decision making exercise the officers were asked to discuss the incidents and come to a group decision on the associations between the incidents. Finally, the officers were presented with an MSA showing the relationship between the incidents according to the variables which they had selected as being the basis of their linking.

5.5 The Incidents

Ten summaries of the incidents were used, drawn from the victim statements of the attack. The attacks are labelled 1 to 11, with no number 3. The real connections between the incidents are summarised in Table I.

Table I

Attacker	Incidents
Attacker 1	10, 11
Attacker 2	1, 4, 6, 8
Attacker 3	5, 7, 9
Attacker 4	2

Table I. The real connections between the ten incidents used in the decision making exercise.

5.6 The Group Decision

At the start of the session the individual group members were asked for their opinions of which of the attacks were linked.

The original opinions are shown in Tables II to IV below.

Attacker	Incidents
Attacker 1	1, 6
Attacker 2	8, 10, 11
Attacker 3	2, 4, 5, 7, 9

Table II. The connections between the ten incidents made by detective one.

Attacker	Incidents
Attacker 1	1, 6
Attacker 2	2, 5, 7, 8, 9, 11
Attacker 3	4, 10

Table III. The connections between the ten incidents made by detective two.

Attacker	Incidents
Attacker 1	1, 6
Attacker 2	2, 4, 8, 10, 11
Attacker 3	5, 7, 9

Table IV. The connections between the ten incidents made by detective three.

After discussion of each police officer's connections between the incidents, and the aspects of the attack which led them to those conclusions, the police officers were asked to come to a group decision.

However, at the end of the group discussion the officers were content to disagree. That is to say that no group decision was reached. The group members were prepared to agree that incident 1 and 6 were by the same attacker, and the rest were in some disagreement. All the group members still held their original view points.

Interestingly, the officers claimed that the structure of the police force is such that no group decision need be made. Having put forward their opinions the group were happy to go along with the opinion of the superior officer. This result highlights the importance of assessing the group processes and social psychological variables at work within decision making groups. In any real decision making situation a decision support system must compliment the existing social and hierarchical structure of the organisation.

It is for this reason that the proposed continuation of the research focuses directly on issues such as leadership, communication and cohesion of real working groups.

Using the attributes which each of the officers considered to be most important in making their own personal decision, a matrix was constructed and MSA run on the data.

The matrix of variables drawn from the police officers criteria is shown below. (N=Not an attribute of the attack, Y=Yes, an attribute of the attack)

Table V.

Attribute of Attack	1	2	4	5	6	7	8	9	10	11
Article on victim's head	N	Y	Y	N	Y	N	Y	Y	N	N
Tied victim	N	Y	N	N	N	N	N	N	Y	Y
Wore mask	N	N	N	Y	N	N	N	N	Y	Y
Theft	N	Y	N	N	N	N	N	Y	N	Y
Covered victim's eyes	Y	Y	N	Y	N	Y	N	Y	Y	N
Shows need for reassurance	N	Y	N	Y	N	Y	Y	Y	N	N
Similar behaviour pattern	N	Y	N	Y	Y	N	Y	N	Y	N
Fingers in victim's mouth	N	N	N	Y	N	Y	N	Y	N	N
Turns victim over	N	Y	N	Y	N	Y	Y	N	N	N
Destroys forensic evidence	N	N	N	N	N	N	Y	N	N	Y
'I just want to feel you'	Y	N	N	N	Y	N	N	N	N	N
Occupies premises	N	N	N	N	N	N	N	N	Y	Y

Table V. Matrix Derived from the Officers' Classifications.

5.7 Multidimensional Scalogram Analysis

The MSA plot of the ten incidents is shown in figure 1.

The MSA plot, based on the police officers own distinctions shows a number of groupings of the incidents. The most obvious inference that can be made from the plot is that attacks 10 and 11 are quite different to the other attacks in the series. Whilst detectives one and three had linked these crimes, they former had also associated attack number eight, and the latter 2, 4, and 8.

All the police officers had linked attacks 5, 7, and 9 in their original conclusions, however, two of the officers had included attack number two in this possible series. The proximity of attack number two in the MSA shows the similarity they drew in the variables they considered.

Although all the police officers correctly linked incidents 1 and 6, none of them made the correct association between these two indecent assaults with the rapes of attacks 4 and 8. However, it is particularly interesting that these four attacks are still to be found in the same area of the plot indicating their similarities on the variables which the police officers were considering. It was to be connections like this which held the most interest for the police officers when the true connections were revealed.

In conclusion then, the MSA plots derived from the detectives own observations of the characteristics of the attacks show that some of links made by the detectives are represented in the space. However, there are also similarities between incidents which are truly connected which the officers did not see in their first analysis of the incidents.
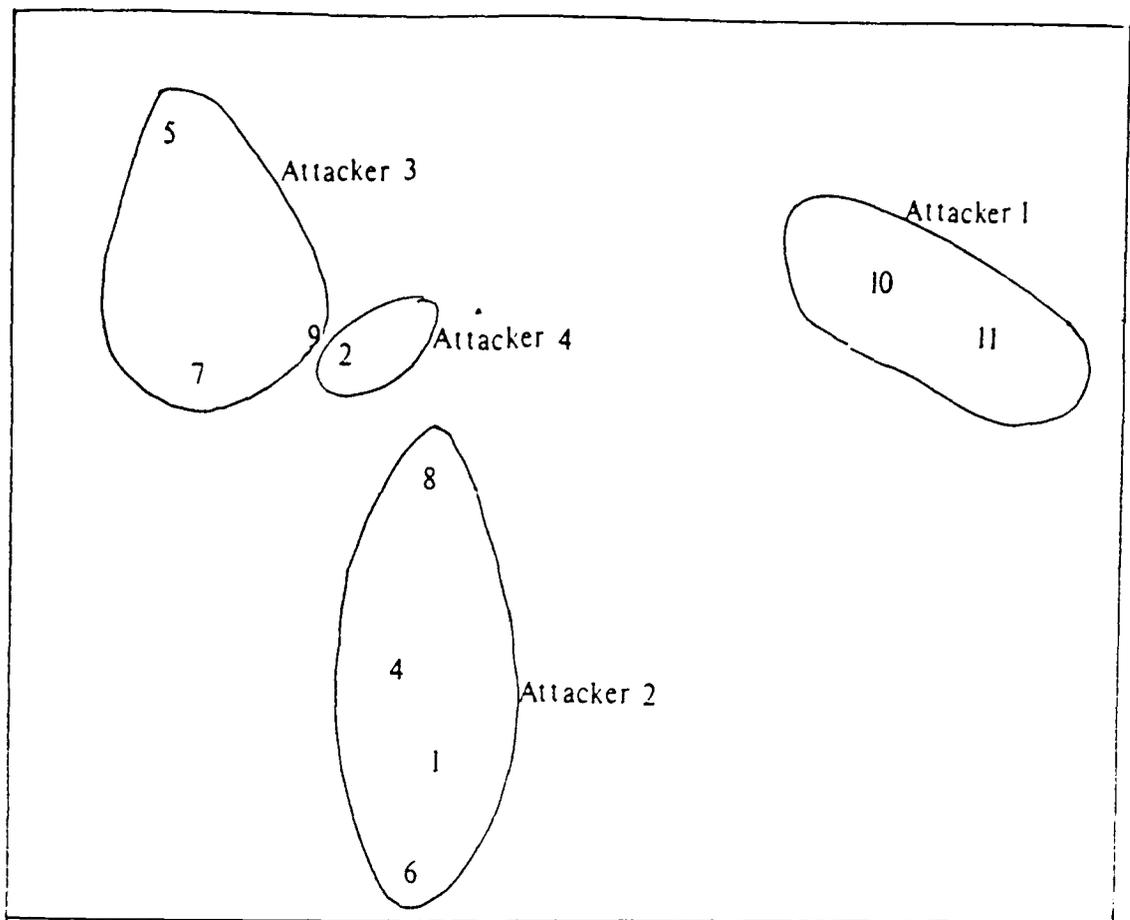
Figure 1. Overall MSA of 11 rapes produced from the classification of behaviour in the offenses shown in Table V. The linked crimes are indicated.

5.8 Summary

In summary, when tested in a decision making situation applicable to criminal detection, the system was shown to be effective in its pilot stage. Using the data considered by three experienced detectives in the linking of serious sexual attacks it was possible to demonstrate that MSA revealed similarities between the crimes committed by the same attackers. The representation revealed not only the associations which were obvious to the officers, but also some of the true connections which they had not made, even though the programme worked only with the similarities and differences between the attacks which had been derived by the detectives themselves.

CHAPTER SIX:
GROUP DECISION MAKING IN THE LINKING OF SERIAL CRIME

Five small groups of three to six police officers took part in group exercises in the linking of serial crime. Twelve victim statements were edited for the study, so that the only information available to the detectives was the behaviour of the offender throughout the attack. Information regarding the location of the incidents and the description of the offender was removed. Three statements were taken from series committed by each of four known offenders.

Qualitative similarities and differences between the incidents were elicited from each of the detectives and they were asked to indicate which of the constructs they had generated they considered to be the most important. They were then required to decide which of the incidents were linked, both individually and following a group discussion. Each of the participants was also asked to fill in a shortened version of the questionnaire to indicate their experience of the group decision making session.

Results show that across the twenty four detectives who took part there is considerable variation in the incidents thought to be linked. The group solutions also represented a wide range of accuracy from almost all of the correct links to none at all.

A variety of representational techniques are used with the data. Representation using Multidimensional Scalogram Analysis (MSA) is used to illustrate the different perspectives of the officers within the group in comparison to one another and to the group decision. Partial Order Scalogram Analysis (POSA) is used to represent the subjective ratings of the group experience and to compare the perceptions of the group members to objective measures of success.

The qualitative constructs which the detectives nominated as most important within each group were combined and analysed using MSA. This representation can be considered a logical combination of their views. However, in all five groups the MSA representation more accurately reflected the true connections between the incidents than it did the detectives' group decision. These results suggest that group processes can distort problem solving so that sub-optimal solutions are produced. A clear role for an on-line decision support system is indicated.

CHAPTER SIX:
Group Decision Making in the Linking of Serial Crime

6.1.1 Introduction

The research discussed so far has been directed toward establishing a series of representational techniques to mod_l the decision making process. It has been suggested that the modelling techniques have the potential to help structure both the task and the process of group decision making.

However, the research has indicated that the representational techniques best model decision making when i) the group is working with concepts of relevance to their decision making and ii) all the group members' opinions are taken into account.

Analysis of the student housing decision making groups has demonstrated that when the group is making a decision based on the criteria thought to be important to all the members, the entities (houses) are located in the same region of the plot, i.e. possessing the same characteristics. Overlaying the opinions of the group members as shaded regions, it is possible to model the individual input to the decision. This indicates which people's views have been included in the group decision. Thus the process of an undemocratic group can be visually represented. However, if the criteria which positioned the points in the plot, i.e. everyone's opinions, are not taken into account, the selected options are not likely to be in the same region of the plot.

However, rather than being a restriction to the application of the technique, this distortion is of interest in itself. The combined modelling of process and the extent of modelling of task give 'post hoc' indication of the structure of the group's communication system.

The aim of the current section is therefore to apply the modelling techniques to qualitative material elicited from groups of police officers concerning the possible links between a number of serious sexual attacks.

This series of studies tests the modelling technique with twenty-four British police officers from across the country. The officers worked in five small decision making groups, all considering the same material from twelve real rape cases.

6.1.2 The Decision Problem.

The police officers were given a set of twelve victim statements from rape cases committed by known offenders. There were four different offenders, each of whom had committed three rapes.

The statements were edited so that the only material available for the officers was qualitative aspects of the offenders' behaviour during the attack (copies of the material given to the officers can be found at the end of this chapter). In a normal enquiry they would of course

also have locations, descriptions of the offender etc. However, to test fully the potential of MSA representation, the study worked with the type of material which is the most difficult to use to draw inferences in an enquiry.

The officers' task was to decide, first individually and then as a group, which of the offences were attributable to each of the four offenders, based solely on qualitative similarities and differences in their behaviour.

This type of decision task is different to those considered in the earlier pilot studies in two important ways;

   i)   In both the student housing problem and the research awards example the decision makers' task is to assign options to one of two classes; accept or reject. In these cases instances are similar in that they do or do not possess the characteristics thought to be desirable. It is this particular combination of characteristics which makes them similar to one another.

          The task for the police officers is to assign the options (offences) to one of four categories, one for each offender. In this case the instances are similar in that they possess the characteristics thought to relate to consistencies in one person's behaviour.

   ii)   In many decision making problems there is no concept of a correct or an incorrect decision. In the pilot studies the modelling techniques serve to improve the <u>means of reaching the decision</u> for the group, either by structuring the task, or by improving the representation of the group members' views and therefore the satisfaction of the group with the decision. By structuring the decision it has been suggested the representation can help the group to reach a decision which they <u>feel</u> is best. Such "feelings" are important both to maintain group cohesion and to ensure acceptability of any system in use.

          However, in this type of criminal decision making the issue of accuracy is also of prime importance. Simply feeling good about the links made between the attacks is clearly not enough. For this type of decision making it is necessary to consider whether the representations provide an accurate picture of the similarities and differences between the incidents.

In the following section two issues are therefore considered i) modelling and ii) accuracy.

i) Modelling

Firstly, the extent to which the group's opinions of the links between sexual attacks can be modelled using MSA will be assessed. Thus given the same information, the decision made by the police officers and the decision implied by the MSA are compared.

If the MSA representation is taken to be a logical and democratic combination of the individual viewpoints, then any deviation from that can be seen in terms of what goes on in the group. In this case then, it is possible to consider whether the police officers came to a

logical solution to the problem on the basis of the information they have.

ii) Accuracy

The second issue is not simply whether the group solution was logical on the basis of the information used, but whether the decision was accurate. By considering the accuracy of the group's decision and the solutions suggested by the representation, it is possible to assess whether the social interaction (the "committee meeting") increases or decreases the accuracy of the group of experts.

6.2 Modelling and Accuracy

If MSA models the decision which the group makes, whether it is an accurate or inaccurate one, this implies that feedback of the representation could make the decision making process easier. Whether the decision they make is right or wrong has more complicated implications. If the decision the police officers come to is incorrect there are a number of possible explanations for their failure.

i) The officers had all the information necessary to make the decision but were unable to structure the amount of material in order to reach an accurate decision.

ii) The officers had all the information necessary to make the decision but the combination of the material was distorted by group processes. For example, a dominant and inaccurate leader.

iii) The officers did not have (or did not use) the information which was necessary to make an accurate decision.

The interaction of the two issues of modelling and accuracy produce a more complicated set of hypotheses for the present study.

i)   Representation of the group decision. If the group are able to successfully combine the information they are using, and group processes do not distort their solution, the MSA will represent the group decision.

ii)   Representation of the true connections between the incidents. If the attributes generated by the officers are appropriate in distinguishing between the different offenders, the MSA will represent the true links between the offenses.

iii)   Representation of an accurate decision. If the officers are able to successfully combine the appropriate attributes in distinguishing between the incidents, both the MSA and the officers' decision will reflect the true links between the incidents.

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6.3 Procedure

In the first session each police officer was asked to read through the twelve statements and familiarise themselves with the incidents. They were then asked to identify each qualitative feature of the incidents which they thought to be important in linking the incidents and to list the incidents which possessed that characteristic. These classifications were then filled in on forms, one set for each officer. An example of a completed form is shown in Appendix B of this chapter. Each police officer generated a large number of characteristics or attributes and when they had completed the task they were asked to 'star' those that they believed to be the most important.

Following each individual's assessment of the twelve cases they were asked to make their own individual judgement of which of the cases were linked. This was so that the individual's judgements could be recorded prior to the influence of the group, and therefore be used to consider the extent to which the individual members' views were taken into consideration in the final group decision.

In the second session the police officers spent approximately one hour discussing the incidents and came to a group decision as to which of the incidents were linked.

6.4 Accuracy of Individual and Group Decisions

6.4.1 Measuring Accuracy

Tables I to V summarise the decision made by the members of the five decision groups, both individually and as a group.

The top row of the table shows the true connections between the incidents. The second row of the table shows the group decision in comparison to the truth, and each subsequent line shows an individual's judgement within that group. Columns X and Y of the tables give a numerical summary of the decision for use in future analysis (see section 4.8). Column X summarises the number of links which were correctly identified, both for the group and for each of the individuals. The score is therefore a measure of the group and the individuals' accuracy.

Thus for example the true connections can be represented schematically;

A1 - A2	B1 - B2	C1 -C2	D1 - D2
A2 - A3	B2 - B3	C2 - C3	D2 - D3
A1 - A3	B1 - B3	C1 - C3	D1 - D3

(Score twelve)

Table I Group A

Truth	1 7 10	3 5 12	4 6 9	2 8 11	X	Y	Comment
Group Decision	1 7 2	3 5 12	4 6 9	10 8 11	8		
P 1	1 6 8	3 5 12	4 2 7	10 9 11	3	4	
P 2	1 7 2	3 11 12	4 6 9	10 8 5	5	8	
P 3	1 7 11	3 9 12	4 6 10	2 8 5	4	3	
P 4	1 7 2	3 5 12	4 6 9	10 8 11	8	12	Absent from Group

Table V Group E

Truth	1 7 10	3 5 12	4 6 9	2 8 11	X	Y	Comment
Group Decision	1 6 10	9 5 12	2 8 3	4 7 11	3		
P1	8 3 7	10 5 12	2 1 11	4 6 9	5	2	
P2	8 5 7	3 9 12	2 1 11	4 6 10	3	2	
P3	1 2 10	3 5 12	7 8 9	4 6 11	5	3	
P4	1 7 4/3	9/6 5 12	2 8/10 11		-	-	Unwilling to make decision

Table III Group C

Truth	1 7 10	3 5 12	4 6 9	2 8 11	X	Y	Comment
Group Decision	1 7 5	3 11 12	4 6 8	2 10 9	3		
P1	1 7 10	3 11 12	4 6 9	2 5 8	8	5	
P2	12 9 5	3 11 7	4 6 1	2 10 8	3	3	
P3	1 11 10	3 5 8	4 6 2	7 9 12	3	1	
P4	- 9 5	3 11 12	4 7 -	2 10 -	1	4	Unwilling to make decision
P5	1 7 11	3 5 8	4 6 9	2 10 12	5	3	
P6	1 7 11	8 5 12	4 6 2	3 10 9	3	3	

Table IV Group D

Truth	1 7 10	3 5 12	4 6 9	2 8 11	X	Y	Comment
Group Decision	8 7 10	3 5 12	4 6 9	2 1 11	8		
P1	2 7 10	3 5 12	1 6 9	8 4 11	6	5	
P2	8 7 10	3 11 12	4 6 9	2 1 5	ل	8	
P3	11 5 10	3 7 12	4 6 8	2 1 9	2	3	
P4	5 9 10	3 8 12	4 6 7	2 1 11	3	5	

Table II Group B

Truth	1 7 10	3 5 12	4 6 9	2 8 11	X	Y	Comment
Group Decision	1 6 8	3 9 11	2 5 7	4 10 12	0		
P1	4 6 8	3 7 12	2 1 11	2 1 11	3	0	
P2	1 6 8	3 9 11	4 10 12	2 5 7	0	12	
P3	1 11 10	5 8 12	4 6 7	2 3 9	3	1	
P4	1 7 2	3 8 12	5 6 9	4 10 11	3	2	

Tables I to V show the Group and Individual Solutions to the Linking Task. Column X indicates the Accuracy of both the Individuals and the Group. Column Y indicates the number of each individual's links that were represented in the Group Decision.

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One correct series represents three correct links, A1 to A2, A1 to A3, and A2 to A3. Therefore if all links are made correctly a score of twelve is achieved. However, because the task is not open ended, once three series have been identified correctly the third follows logically. Thus a score of eight has only one link mistaken, and so the score beyond 8 is twelve. eg

A1--A2--A3 B1--B2--B3 C1--C2--D3 D1--D2--C3
(Score eight)

Thus there are only 9 degrees of freedom so a score of nine is more accurately a description of success.

This same scoring system is applied to the individuals' representation in the group decision. Thus column Y at the end of the tables contains the individuals' scores in terms of the number of their links which were actually represented in the group decision. This score can vary from zero, indicating that none of the links which they originally made themselves were made by the group, to twelve indicating that the group made exactly the same decision as that particular individual. This score therefore represents the individuals' <u>influence</u> on the group decision.

Examination of these results (summarised in Table VI below) show that at the individual level there is a wide range of accuracy in the officers' original assessments of the links between the incidents .

Number of links	0	1	2	3	4	5	6	7	8	9
Number of officers	1	1	1	9	1	5	1	0	2	0

Table VI
Distribution of Accuracy of the Individual Officers

Whilst none of the officers had the solution completely right from the start, there were two of the twenty-four officers who had a score of eight indicating just one mistake in their judgements. On the other hand there was one officer who scored zero indicating that he had not at that stage identified any of the links correctly. Similarly, with the group decisions, of the five groups, two got a high score of eight (one mistake), one group got no correct links and the remaining two got three links correct.

In considering this range it is particularly interesting to find that although they all started with the same information some groups of officers can be so close to a correct solution whereas others can be so far from it. The reasons for these differences is one of the areas which should be given careful consideration in future research studies. However, a number of possible explantions for group success can be considered;

i) Groups that were more accurate chose to consider the differences between the incidents in terms of attributes which were successful in distinguishing between the incidents.

ii) Groups that were more accurate considered the attributes in a more systematic way, therefore being more successful in structuring the information.

iii) Groups that were more accurate were less influenced by distorting group processes.

It has been hypothesised that representation using MSA can have a positive impact on accuracy both in terms of structuring the material (ii) and by focusing the group's initial view on a 'democratic' solution, where everyone's views are given equal weight (iii). The proposed 'parallel system' is aimed at ensuring that the appropriate type of material is utilised on the basis of extensive background research.

6.4.2 The Actual Links

Tables VII to XI show the distribution of links made by the officers who took part in this study. The tables show that there is a wide variety of possible links as perceived by the participants. The summary table (Table XII) shows that almost every incidents has been linked to almost every other incident by someone. There is very little consensus amongst these officers. The only true connections that are made with any consistency are those between incident four and incident six, and incident three and incident twelve.

Having established the range of accuracy of the individual and group decisions it is now possible to consider the role of MSA in modelling the decisions, and its potential for increasing the accuracy of the decisions.

6.5 Representation of Individual Decisions

6.5.1 Construction of the Data Matrix

Before the group discussion each individual member of the group was asked to give an indication of their opinion of the true links between the four series of incidents. If these individual links are combined and analysed using MSA the resulting representation should be a logical combination of their views.

This representation can then be compared to the group's decision and to the truth in order to establish the extent to which MSA of individual viewpoints models the group decision, and the accuracy of that representation in terms of the true connections.

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	1	2	3	4	5	6	7	8	9	10	11	12
1	•											
2	2	•										
3			•									
4		1		•								
5			2		•							
6	1			3		•						
7	3	3		1			•					
8	1				1	1		•				
9			1	2		2			•			
10				1	1	1		2	1	•		
11	1		1				1	1	1	2	•	
12			4		2				1	1		•
Incident Number	1	2	3	4	5	6	7	8	9	10	11	12

Table VII. Number of Times Each Link was Made by Officers in Group A.

	1	2	3	4	5	6	7	8	9	10	11	12
1	•											
2	2	•										
3		1	•									
4				•								
5		1		1	•							
6	1			1	1	•						
7	1	2	1	1	1	1	•	.				
8	1		1	1	2	1		•				
9		1	2		1	2			•			
10	1			2		1			1	•		
11	2	1	1	1					1	2	•	
12			2	1	1		1	2		1		•
Incident Number	1	2	3	4	5	6	7	8	9	10	11	12

Table VIII. Number of Times Each Link was Made by Officers in Group B.

	1	2	3	4	5	6	7	8	9	10	11	12
1	•											
2		•										
3			•									
4	1	2		•								
5		1	2		•							
6	1	2		5		•						
7	3		1				•					
8		2	2		4			•				
9			1	2	1	2	1		•			
10	2	2	1				1	1	1	•		
11	3		2				3			1	•	
12		1	1		2		1	1	2	1	1	•
Incident Number	1	2	3	4	5	6	7	8	9	10	11	12

Table IX. Number of Times Each Link was Made by Officers in Group C.

	1	2	3	4	5	6	7	8	9	10	11	12
1	•											
2	3	•										
3			•									
4				•								
5	1	1	1		•							
6	1			3		•						
7		1	1	1		1	•					
8			1	2		1	1	• .				
9	2	1		1	1	2			•			
10		1			2		2	1	1	•		
11	1	1	1	1	1			1		1	•	
12			4		1		1	1			1	•
Incident Number	1	2	3	4	5	6	7	8	9	10	11	12

Table X. Number of Times Each Link was Made by Officers in Group D.

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	1	2	3	4	5	6	7	8	9	10	11	12
1	•											
2	3	•										
3			•									
4				•								
5			1		•							
6				3		•						
7			1		1		•					
8			1		1		3	•				
9			1	1		1	1	1	•			
10	1	1			1	1	1			•		
11	2	2			1		1				•	
12			2		2				1	1		•
Incident Number	1	2	3	4	5	6	7	8	9	10	11	12

Table XI. Number of Times Each Link was Made by Officers in Group E.

	1	2	3	4	5	6	7	8	9	10	11	12
1	•											
2	10	•										
3		1	•									
4	1	3		•								
5	1	3	6	1	•							
6	4	2		15	1	•						
7	7	6	4	3	2	2	•					
8	2	2	5	3	8	3	4	•				
9	2	2	5	6	3	9	2	1	•			
10	4	4	1	4	4	3	3	4	4	•		
11	9	4	5	3	1	1	4	2	2	6	•	
12		1	13	1	8	0	3	4	4	3	3	•
Incident Number	1	2	3	4	5	6	7	8	9	10	11	12

Table XII. Number of Times Each Link was Made by Officers in all Groups.

Tables XII to XVII. Attributes Selected as the Most Important in Linking the Incidents by the Officers in Each Group. Where too many are selected for the analysis the attributes used in the MSA are indicated in the table.

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The data matrix for this MSA is of the type shown below;

Incident	P1	P2	Pn
1	A	A
2	A	C
3	A	B
4	B	D
5	B	D
6	B	C
7	C	B
8	C	A
9	C	D
10	D	A
11	D	B
12	D	C

In this matrix the links made by each person are represented as a column of data where the same character is assigned to the linked incidents. There is no indication of which offender is which, simply an indication of which offenses are linked to which. By analysing the profiles of scores in a matrix of this type MSA will represent the distance between each pair of incidents in space so that the more individuals who make that link, the closer together they will be in the plot. Indeed if all of the group members linked two of the incidents then the two incidents will have the same profile of scores and will be plotted as the same point in the space.

The hypothesis is therefore that if the group make a decision which is a logical combination of their individual decisions, then the MSA should reflect the links eventually made by the group. Therefore when the group decide on their collective view of the linking, if this is a rational combination of the individuals' decisions, it should be possible to draw the links onto the plot so that the three attacks for each attacker fall into clear regions.

6.5.2 Combining Information to Model the Decision

Figure 1 shows the MSA combination of views for decision group one. Figure 1a to 1f show the individual officers links which went to make up this combination.

This plot demonstrates that the group have made a decision which is not predicted from a logical sum of their individual views. Whilst the triangle on the bottom left of the plot is in a clear region of its own, suggesting a representative choice, the other triangles overlap to a large extent and therefore are not representative of the 'objective' combination of the individuals' decisions.

This shows that the group decision cannot be modelled from a simple combination of individual viewpoints. Thus the processes which are inherent in the group decision making have had an influence on the group to the extent that the combination of their views is

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MSA on Police Decision Group One

Offender 1　Offender 2　Offender 3　Offender 4
　　□　　　　△　　　　○　　　　*

Individual Judgements
The Group Decision
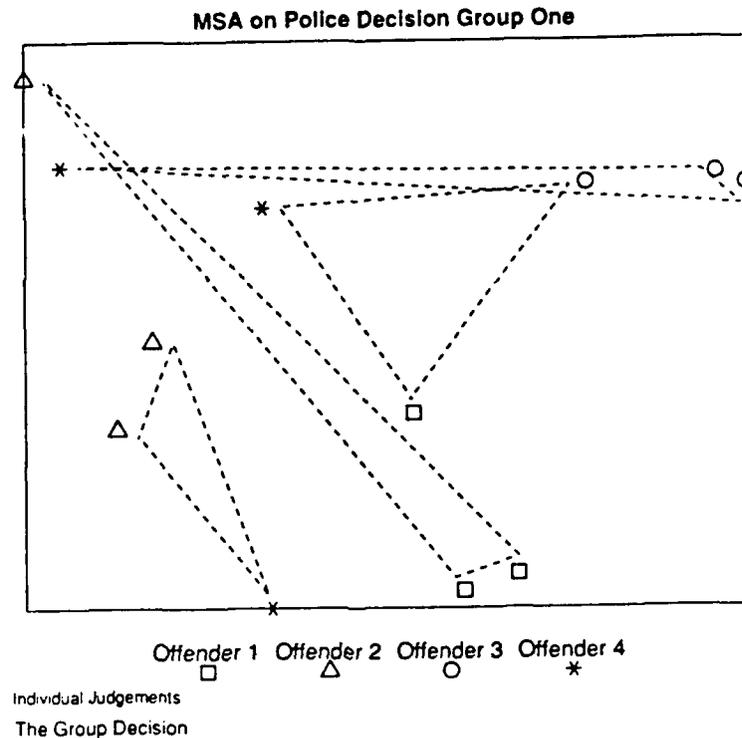
Figure 1. Configuration of Points Generated by MSA of Officers' Individual Decisions. The Group's Decision is Shown by Joining the Linked Incidents to Form 'Triangles'.

significantly altered. It is certainly no surprise that group processes alter the outcome of a group decision. However, the aim of the following section is to see whether the processes of the group interaction were beneficial to the group decision in this case.

6.5.3 Combining Information to Model the True Connections

If group decision making was simply a matter of combining views in a logical way there would be no need for the people to meet. The assumption is that the interaction of a group of individuals produces a better combination than the sum of their individual knowledge. This raises the question of whether the group's 'illogical' combination (their decision) gets closer to the true solution than the logical combination (the MSA). The principle that the group processes are valuable in themselves and are likely to generate a better solution than a collection of individual experts suggests that the MSA model of combined individual views would not model the decision and the group decision would be more accurate.

However, the results show that the logical combination of the individuals' viewpoints is much closer to the true solution than the group decision. Figure 1 shows that group one did not correctly link one whole set of three incidents. The best they achieved was two out of three
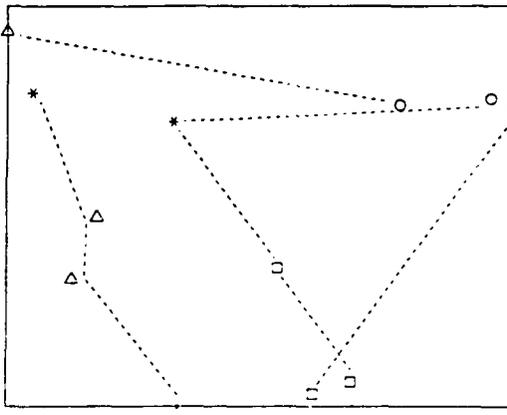
Figures 1a to 1f. MSA Plot of Officers' Individual Decisions Showing the Links m de
by Each Officer Joined as 'Triangles'.

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links for offenders one, two and three. However, when the non process sol·tion (combination of the individuals' independent decisions represented by MSA) is joined into triangles according to the true links it can be seen that the incidents carried out by offenders one and three are quite distinct (see Figure 2). This means that the logical combination of the individual officers' views is closer to the truth than the solution which they themselves generated by group discussion. MSA models the truth better than the decision. Had this diagram been used even in the most simple way (see Figure 3) then the group would have made only two mistakes giving them a score of eight rather than a score of three.

6.5.4 Summary

In terms of modelling, it has been shown that for this particular group the group decision making context had an influence on their decision such that the final decision did not represent a logical combination of their individual viewpoints.

There are three possible reasons for the combination of individuals' original opinions not being reflected in the group decision;

1) Group Processes

As discussed above, it has been assumed that the dynamic interaction of a group of decision makers is more beneficial than a static combination of their views. However, in real decision making groups many psychological processes are at work which may influence the group decision in a positive or negative way. For example, leadership, status or other aspects of the authority of their viewpoint may mean that certain people's opinions take precedence over those of other members. The problem is that it is not always the person who is accepted as the most senior or most likely to be accurate who actually does have the true solution.

Whilst the proposed system aims to work with, not replace group processes, MSA gives equal weight to everyone's views. Thus attention is focused on the views of the whole group of experts from the outset.

2) No Commitment to the Individual Decisions

The second possible explanation for the combination of individual views not representing the group decision lies in a lack of commitment to the initial decisions made by the individual. It is easier for the group to have an influence on the views of an individual if they were not committed to that view in the first place. For example, some of the police officers made an individual decision on the first day, but said that they were not at all sure at this stage. These people would be more easily swayed by the others in the group.

By the same argument it is possible that the extra time to consider the material on the second day gave the police officers a chance to consider different links to their original opinions. However, if group one is representative of the other groups, this would have worrying implications; deeper consideration leading to less accurate links.

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Offender 1　Offender 2　Offender 3　Offender 4
　□　　　　△　　　　○　　　　*

Individual Judgements
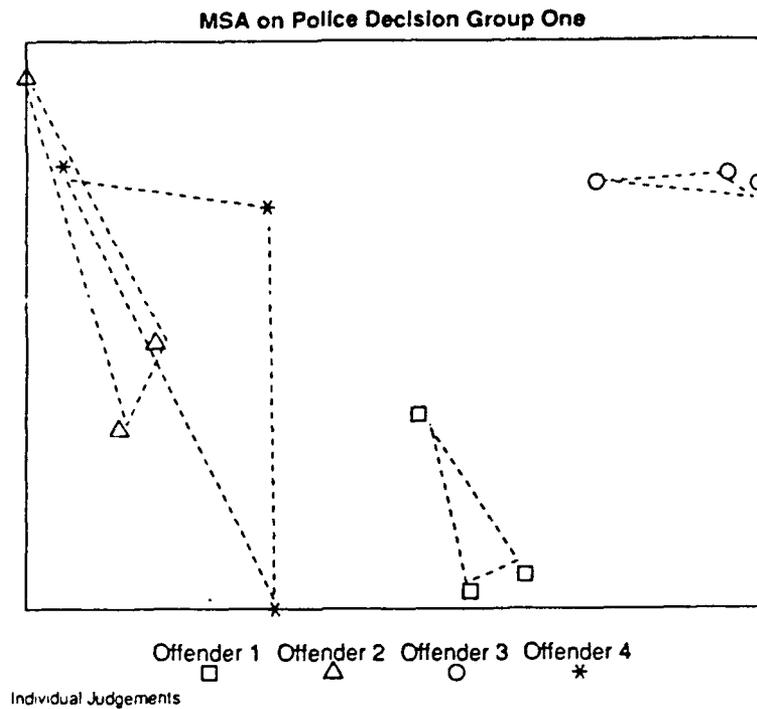
Figure 2. Configuration of Points Generated by MSA of Officers' Individual Decisions. The True Connections are Shown by Joining the Linked Incidents to Form 'Triangles'.

Offender 1　Offender 2　Offender 3　Offender 4
　□　　　　△　　　　○　　　　*
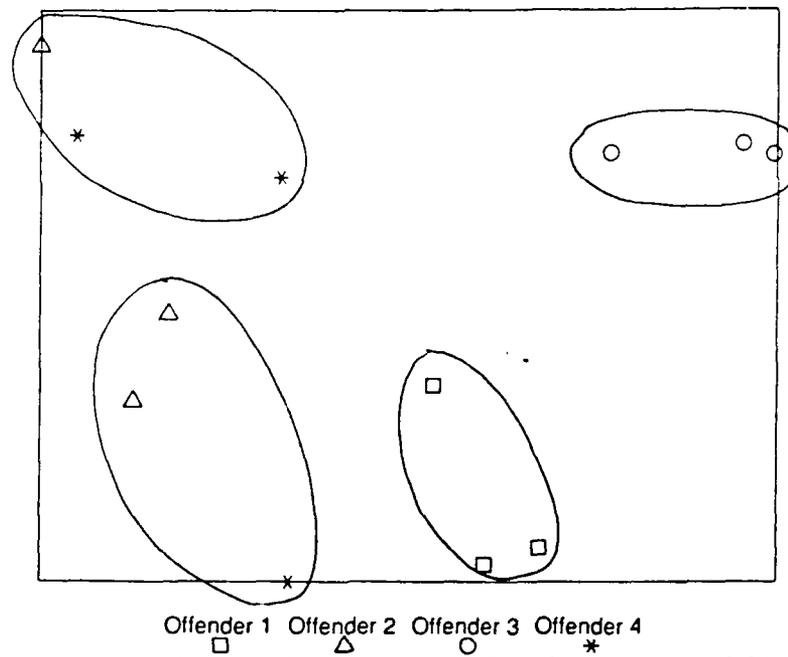
Figure 3. Configuration of Points Generated by MSA of Officers' Individual Decisions, Showing Possible Solution to Decision Problem (Scores for Accuracy).

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3) Performance Deficit

The final consideration may be thought of in terms of the information used for the decision. If poor information synthesis can be used to explain inaccuracy in the group, then it certainly could be true of the individual officers' decisions. For example, whilst the officers may be confident with the similarities and differences which they have drawn out of the statements, they have been unable to combine them in a meaningful way in order to make an inference about the links.

Thus the decisions which they come to as individuals are not related to the relationships between the incidents in terms of their important constructs. It may be the case then that when the group starts to structure the similarities and differences in a more logical way the links they come up with are different to any of the individuals' links. This would explain why the MSA combination did not model the group decision.

Points two and three above have raised the issue that the individual decisions may not be the best way of modelling the group view, and that it is the actual attributes, or similarities and differences between the incidents which must be considered.

This argument suggests that the individual decisions are not summaries of the person's distinctions across all their criteria. Rather they are a 'rough' decision based on an inability to assimilate all the information need for the decision.

It would be possible in future research to test this assumption using MSA. By analysing the individual's criteria, and comparing the MSA to their own personal decision it would be possible to test whether their decision is a 'logical' combination of their own material.

Anecdotal evidence suggests that although the decision making groups compare their original decisions at the start of the group decision making session, the group decisions are taken from 'scratch', with reference to the original attributes.

It is therefore necessary to consider whether the group are successful at combining their important attributes in order to establish a group decision on the linking of the incidents, and the role MSA plays in modelling this process.

6.6 Representation of the Important Attributes

During the elicitation stage of the decision making exercise each officer was asked to generate as many similarities and differences between the incidents as he or she felt relevant. Although there was individual variation between the officers in the actual number of attributes they generated, overall a vast number of different attributes were mentioned. This data has been combined to form a data base which will be used to assess the utility of the attributes in drawing links between serial crimes. However, in order to analyse the attributes in relation to the group decision, each officer was asked to indicate the attributes which they felt were the most important for the linking of these incidents.

These constructs were combined for all the group members and a matrix developed which indicated on the grounds of each attribute whether or not each incident possessed that characteristic or not.

The matrix was therefore of the form;

	Attributes			
Incidents				
	A1	A2	A3	An
1	1	1	2	2
2	2	2	2	2
3	1	2	1	2
4	2	1	1	1
n	1	2	1	1

The cells indicate that each attribute is (2) or is not (1) present in each of the incidents.
In this way the attributes are directly attributable to the officer who proposed them. Thus for example, A1, A2 and A3 may have been nominated by officer one and A4 and A5 by officer two etc.

The attributes which were analysed in this way for each of the decision groups are shown in tables XIII to XVII. These tables show there is some overlap in the constructs thought to be important by each of the five decision groups. For example, 'demand for oral sex' is considered to be important by all five of the groups.

The data matrices therefore represent the attributes thought to be important by the police officers within each group, and their own classification of the incidents on those attributes. The five data matrices were analysed using MSA.

The resulting MSA plots therefore show the similarities and differences between the incidents as perceived by each group as a whole. Thus taking all the attributes which are thought to be important by the group members, MSA plots the incidents in such a way that those that are more similar are closer together in the plot and those that share little in common are further apart.

Once again two distinct issues are considered;

       i) Does the MSA model the group decision ?
       ii) Does the MSA improve the accuracy ?

Table XIII

Attributes Thought to be Important by Group A
Told to lie face down 'suck it' Length intercourse lasted Intercourse face down penis in mouth slow movements supported with hands threat to cut throat sympthy to victim ejaculation wanted affectionate response oral sex unafraid of face to face contact type of clothing removal intercourse from rear

Table XIV

Attribues Thought to be Important by Group B
*Hand over face & attack from behind Threats to kill *Requests victims to do something *Victim to lie face down 'cut throat' emphasis on oral sex *Knew the area *oral sex preplanned attack Victim questionned Knew the victim violent rape *opportunist remained with victim after *Talkative/asked things of victim *Threats of violence or death *removed victims clothing 'suck it' kneeling by offender *clothing taken over head *asked address *ejaculated in victim's mouth conversation participation

* denotes constructs used in MSA

Table XV

Attributes Thought to be Important by Group C
Self esteem Attacks from behind Victim asked to remove clothes Clothing removed by offender Oral sex after intercourse oral sex before intercourse Intercourse lying on back Intercourse lying on front supports self with arms Threats to kill Threat to cut throat Threats of violence Asks victim for personal details Attempts to befriend victim Threat if police informed

Table XVI

Attributes Thought to be Important by Group D
Grabbed across throat Intercourse from rear Comments during Intercourse Demand for oral sex Threats made after incident Walked away immediately after Fetish with breasts Callous attacks

Table XVII

Attributes Thought to be Important by Group E
*Removes upper clothes *Offenders vocabulary Interactions (conversations) *Bothered by passive reaction *Upper clothing removed *oral sex with ejaculation *supported self ejaculated (general) *Oral sex Cut throat Asks victim to touch him *Nothing said after *Lie face down *Intercourse slowly

*denotes constructs used in feedback MSA

Tables XII to XVII. Attributes Selected as the Most Important in Linking the Incidents by the Officers in Each Group. Where too many are selected for the analysis the attributes used in the MSA are indicated in the table.

6.7 Modelling the Decision.

Figure 4 to 8 show these MSA plots, one for each of the decision groups. The same configuration is presented twice. The links the groups made after the group discussion shown on the right hand side and the true links between the incidents shown on the left hand side.

Three different types of modelling are shown;

> a) Modelling the individual viewpoints. The MSA plots are derived from the combination of the attributes thought to be important by the individual members of the groups A and B **prior** to the discussion.

> b) Modelling the Group View. The attributes which the group actually considered during the discussion were analysed in order to model the attributes thought to be important by the group. (Groups C & D).

> b) Feedback of Individual Viewpoints. The MSA of individual viewpoints prior to the discussion was presented to group E to work with during the decision making discussion.

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6.7.1 Modelling the Individual Viewpoints

The first type of modelling using MSA is based on the attributes thought to be important by the individuals in the group prior to the group discussion.

MSA analysis of two groups of officers' attributes are compared to their group decisions. It is hypothesised that if the officers make a group decision which is a logical combination of the similarities and differences between the incidents which are thought to be important by the group members, the MSA representation will model that decision.

Further, it is hypothesised that if the attributes selected by the officers are appropriate to the linking of these particular incidents, MSA will model the true connections between the incidents, regardless of the decision made by the group.

The links between the incidents are drawn onto the plot so as to form triangles connecting the three incidents thought to be linked in each case. The less overlap between these triangles the more the incidents are discriminated in terms of the attributes chosen for analysis.

Two interpretations are presented, the first plot showing the true links between the incidents and the second plot showing the links made by the group following their discussion. Figure 4b shows that on the basis of the individual officer's opinions prior to the discussion, MSA models the connections eventually made by the group on two of the series (3,5 and 12; 4,6 and 9). This suggests that the attributes thought to be important by the individual officers were used by the group in order to make these decisions. Further, comparison with the true links shown in the MSA plot in Figure 4a shows that these two series were correctly identified. On the other hand the links between series two, eight and eleven and one, seven and ten were not made by the officers' in their group decision. The MSA plot demonstrates more similarlity between the true connections than between the decisions on the basis of the officers' own individual attributes. In particular, incidents one and ten are represented by the MSA as possessing much in common on the selected attributes, yet the officers did not make this link. The MSA plot for group B is shown in Figure 5a (the true connections) and 5b (the group's decision).

Figure 5b shows that the decision which the group made was not based on any of the similarities and differences perceived by the officers on their most important attributes. This group was quite unique in that they followed a dominant leader whose ideas on linking were not based on any of the material which the individuals had generated. Consequently the MSA of their information bears no resemblance to the decision they made. On the other hand when the true links are drawn onto this plot, four clear regions relating to the different attackers are revealed. This suggests that had they been able (or willing) to combine their original views in a logical way they would have been considerably more accurate in their eventual decision.

However, whilst the MSA plots which are shown to relate to groups A and B are a logical combination of the information they considered to be important before the meeting, there is no suggestion that they actually used this information to reach the decision once they started to discuss the problem. The following section models the actual information which the officers were using during the discussion.

Figure 4a. MSA of Group A's Combined Attributes.
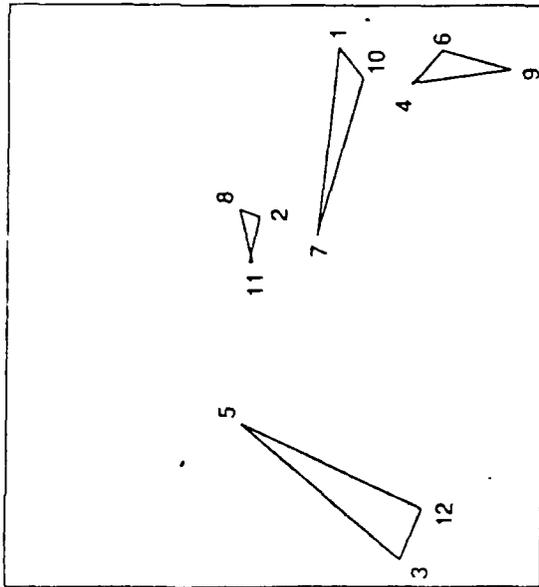
The True Connections

Figure 4b. MSA of Group A's Combined Attributes.
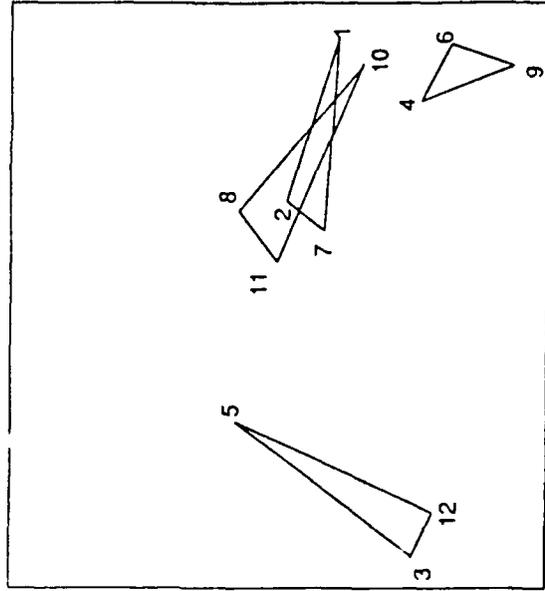
The Group's Decision

Figure 4a and 4b. MSA Plot of Incidents According to the Attributes Thought to be Important by the Members of Group A. The True Connections (4a) and the Group's Decision (4b) are Joined on the Plots.

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Figure 5b. MSA of Group B's Combined Attributes.

The Group's Decision

Figure 5a. MSA of Group B's Combined Attributes.
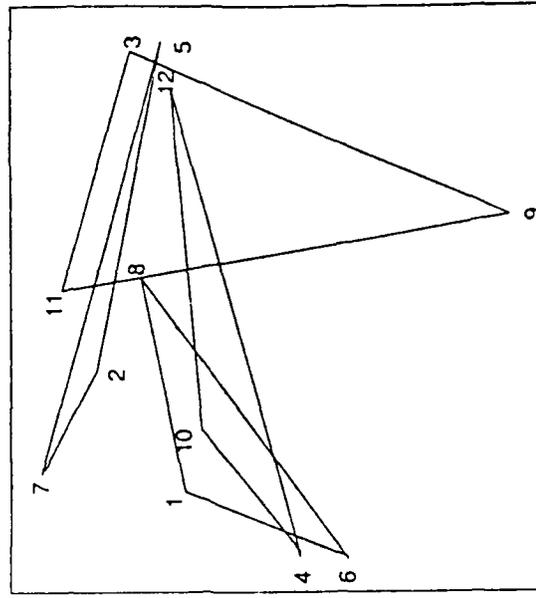
The True Connections

Figure 5a and 5b. MSA Plot of Incidents According to the Attributes Thought to be Important by the Members of Group B. The True Connections (5a) and the Group's Decision (5b) are Joined on the Plots.

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6.7.2 Modelling the Group View

Groups C and D can be compared quite directly because both of these groups constructed a matrix of attributes comparable to the one outlined above from which to work during the group discussion. It was therefore possible to analyse the attribute data which they actually used to reach a decision using MSA.

This then represents the material which they were actually using during the discussion rather than modelling the information assumed to be used during the discussion.

Figures 6 and 7 show the MSA configurations generated from analysis of the attributes shown in tables XV and XVI. In terms of modelling the group decision the right hand plot for group D shows that the MSA partially models the decision. For this group the links between incidents three, five and twelve and four, six and nine are represented in separate regions of the plot. This shows that for these two series of rapes the decision which the group made was derived from qualitative similarities thought to be important by the group members during their discussion. Further, comparison with the true connections shown on the left hand plot demonstrates that these two series were also correctly identified.

However, group D's decision regarding the two remaining series and group C's decision on all four are not modelled on the right hand plots, being represented as 'overlapping triangles'. Comparison with the true connections shows that for both these groups the MSA represents the true connections between these two series better than it models the groups' decisions. The plot for group D is particularly clear in this respect.

This plot (shown in Figure 7a) demonstrates that on the basis of the group of officers' distinctions made during the discussion, MSA clearly models the true connections between the incidents as clear regions in the plot. This result also suggests that the attributes selected by these officers were particularly successful in the linking of these crimes, even if the group were less successful in combining their information.

6.7.3 Feedback of Individual Viewpoints.

In the final example, a sample of the attributes thought to be important by the individual officers were analysed using MSA and the resulting plot given to the group to work with during the discussion.

The group were presented with a 'hard copy' of the MSA configuration showing the relationship between the incidents as plotted on the basis of their own judgements. They were also provided with a series of transparencies which could be overlaid onto the plot. The transparencies represent each of the attributes proposed by the members of the groups, and show a shaded region which enclose all the incidents which possess that attribute.

Before the group discussion began, the officers were given an explanation of what the representation meant, and how they could use it to help them make the decision.

The MSA plot is shown Figure 8a and 8b, again showing the true connections and the group's decision respectively. Figure 8a, demonstrates that on the basis of the officers' own

Figure 6a. MSA of Group C's Combined Attributes.
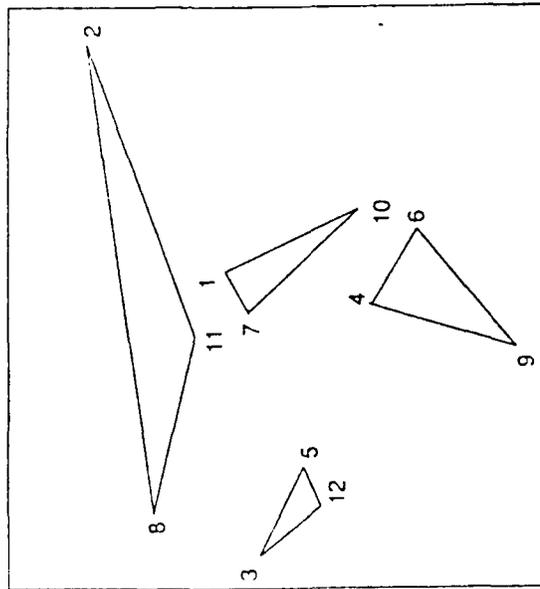
The True Connections

Figure 6b. MSA of Group C's Combined Attributes.
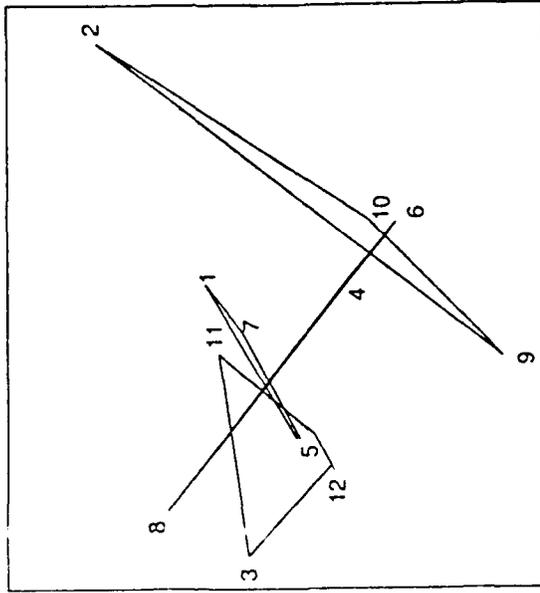
The Group's Decision

Figure 6a and 6b. MSA Plot of Incidents According to the Attributes Thought to be
Important by the Members of Group C. The True Connections (6a) and the Group's
Decision (6b) are Joined on the Plots.

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Figure 7b. MSA of Group D's Combined Attributes.

The Group's Decision

Figure 7a. MSA of Group D's Combined Attributes.

The True Connections
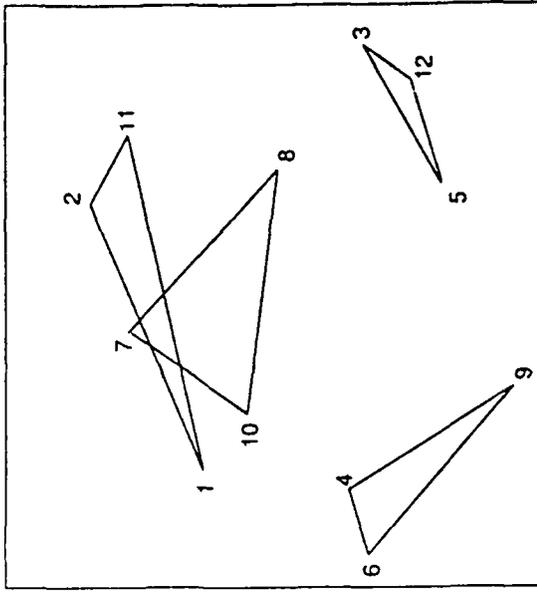
Figure 7a and 7b. MSA Plot of Incidents According to the Attributes Thought to be Important by the Members of Group D. The True Connections (7a) and the Group's Decision (7b) are Joined on the Plots.

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Figure 8a. MSA of Group E's Combined Attributes.
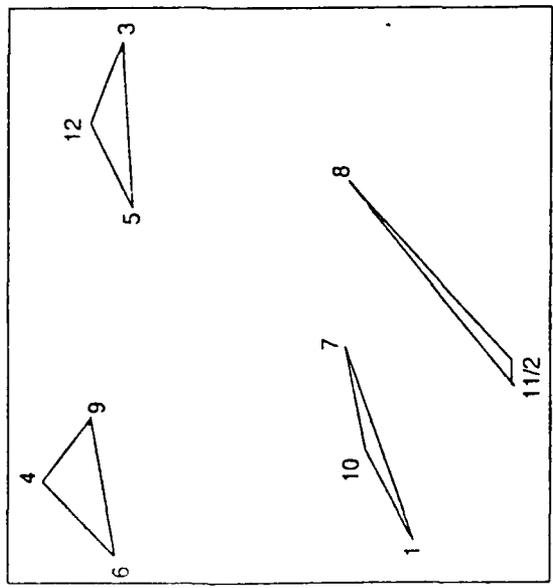
Figure 8b. MSA of Group E's Combined Attributes.

The True Connections
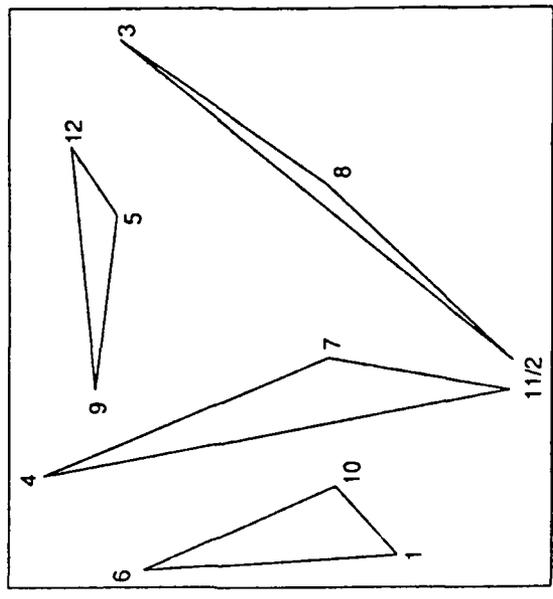
The Group's Decision

Figure 8a and 8b. MSA Plot of Incidents According to the Attributes Thought to be
Important by the Members of Group E. The True Connections (8a) and the Group's
Decision (8b) are Joined on the Plots.

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classifications of the incidents the four series of attacks are well differentiated in the MSA plot. Indeed, incidents two and eleven are represented as the same point in the plot, sharing an identical profile of characteristics. Had the officers used the plot in the most simple way it would be predicted that they would have identified series four, six and nine and three, five and twelve correctly. Figure E_2 shows the connections they eventually made.

The main conclusions that can be drawn from this plot concern the difficulty or the unwillingness that the officers had in using the plot that they were given. For example, even though incidents two and eleven shared identical characteristics the officers did not make this link. Once series four, six and nine and three, five and twelve have been identified on the plot it would be expected that incidents two and eleven would be linked to either eight or one.

The reasons for the decision that this group took can only be accounted for by considering what actually happened during the discussion. Quite early in the discussion the group were convinced that incidents three and eight were linked as both attackers used the words 'I'll cut your throat'. Once three and eight were linked the series 'three-five-twelve' could not be correctly identified. Further, although two of the younger officers quickly understood and tried to use the plot, they had considerable difficulty in focusing some of the older officers attention on the implications it had for their decision. In this particular group there was what can only be described as hostility to the whole principle of the representation. The MSA plot in Figure 8b directly demonstrates the way the plot was not used to make the decision.

The fact that the study failed in this respect perhaps carries as many implications as had it succeeded. Despite a full explanation that the analysis did no more than portray the officers' own views on the incidents, their reaction to it shows how sensitive established experts can be to any attempt to alter the way they do their job. Further preliminary studies with young officers on a special training course have indicated that the representation can be both used and appreciated. However the development of the system must take into account the best way to make this form of decision support both understandable and acceptable to those who will use it.

In summary, comparison of the two plots for all five groups shows that in every case the MSA plot models the truth better than it models the decision which the group made. Thus the logical combination of the officers' own criteria has the potential to 'reach' a better solution than the officers themselves without plots.

However it is quite remarkable at this stage that the criteria which the officers selected for the analysis worked so well in terms of representing the true connections. It is very important to stress that whether the true connections are modelled or not depends on the relevance of the attributes selected. Some attributes may not be relevant at all and so the decision which is suggested by the model may bear no resemblance to the truth. For example, in this series of studies some emphasis was placed on the speech of the offenders in the incidents. In two of the incidents the offender threatened to cut the victim's throat. This did not however turn out to link the two incidents. Thus if the officers had selected a large number of irrelevant attributes the MSA would not have 'worked'. The representation can only be as good as the material put into it.

If the information used by the police officers is inappropriate this suggests the need for a

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parallel system. This system would contain an indication of which information is appropriate to use for the MSA representation and which is not. This kind of data base is currently being developed. This knowledge base can then be linked to the representation as a parallel system of expertise derived from extensive consideration of large data sets and from involvement in live enquiries. By analysing the key variables in criminal and terrorist incidents from existing material it is possible to build up a picture of their relationships in linking incidents.

It is for this reason that a considerable amount of background research must still be undertaken in order to establish the relationship between attributes in sexual attacks (or other areas of interest) in order to establish which facets of behaviour are useful for distinguishing between offenders and which are not. It has been possible to indicate which of the attributes out of the very many generated by the police officers in this study have proved useful in this respect. However, they have only been proved to be useful for the incidents which have been considered in this study. It is therefore necessary to test these attributes and many others to see how far these results are generalisable.

Finally it is necessary to consider the possible reasons why the MSA was more successful at modelling the true connections between the incidents than the officers were at arriving at that decision.

The results of these studies tend to suggest that apart from one or two exceptions, for this series of incidents the attributes that the individuals selected prior to the group decision were not totally inappropriate. This is demonstrated by the fact the MSA plots all give reasonable representation of the truth. Thus they all had the material available to make a reasonably accurate judgement.

However, it is quite different to assume that they considered these attributes during the discussion. For example, group B did not consider the attributes they had generated at all and invented quite new reasons for the links which resulted in failure.

On the other hand, two of the groups studied actually used a matrix of attributes during the discussion. Analysis of those matrices still gave a better representation of the truth than was reflected in the officers' decision.

The relative failure of the police officers in comparison to the MSA representation must therefore be explained in terms of either an inability to structure the material which they were working with or the interference of group processes.

The first section of this chapter of the report showed that a simple logical combination of the views of the individuals using MSA provides a better representation of the true links than that generated by the group discussion. Similarly the previous section has shown that by combining the attributes thought to important to the individuals or the group as a whole the MSA gave a fair representation of the true connections between the incidents.

This suggests that whilst combining the views of a number of experts is likely to increase the

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validity of the decision, the group processes associated with committees have been rather unhelpful in these decision making groups. It was certainly group processes which led group B to come to such an inaccurate solution to the decision problem. In this case one person had an different idea as to how the incidents might be linked, and the whole group followed it. Although there were some attempts from other group members to make this individual justify his views, and indeed to make the group consider their original attributes, the group eventually were convinced by this one individual to follow his (wrong) idea.

The final section of this chapter therefore considers the individual members of Group B's experience of the group processes, as measured by the questionnaire discussed in Chapter Three.

6.8 Perceptions of the Group Process: Analysis of the Questionnaire Data.

In order to investigate the relationship between the objective summaries of the group decision making process and the experience of the group members, each participant was asked to fill in a shortened version of the group decision making questionnaire.

The questionnaire therefore assesses the participants' view of the extent their group was led, the cohesion of the group, the communication and task focus, and the success of the problem solving strategies.

Section 6.4.1 presented tables in which each individual was assigned a score to reflect the number of their original links which were eventually represented in the group decision. Comparison of the number of links represented ('influence') with people's perception of the decision making group should establish whether there is a relationship between perceived and actual input into the decision.

Decision Group B provide the most extreme example of the way that group processes affected the decision making group. For this reason the questionnaire data will be examined to see if any consistent differences in the experience of the members of group B can be revealed. Each individual's role in the group and the number of their opinions which were represented in the group decision are outlined below.

A. Individual A was a Detective Inspector who dominated the group discussion and suggested a quite different way of thinking about the relationships between the incidents. All twelve of his original links were represented in the group's final decision.

B. Individual B was a Detective Inspector who was the first to support individual A's new theory. He openly backed A and accepted the decision although only one of his original links was represented.

C. Individual C was a Detective Sergeant who consistently questioned the validity of A's arguments, requesting further backing for his new theory. He regularly suggested comparing the new links to those which the individuals' had made before the decision. He accepted the decision, adding only that he was playing 'devil's advocate' in order to test the theory. Two of his links were represented in the decision.

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D. Individual D was a Woman Detective Sergeant who took part in the early discussions of attributes but took less of a role once individual A's theory was being discussed. None of her links were represented in the decision.

6.8.1 Comparison of Mean Scores on Each Section of the Questionnaire.

The questionnaire contains items to measure the participants' perceptions of group cohesion, communication, the impact of leadership, the group's problem solving strategies and the extent of task focus. The mean response to items in each of these sections for the four police officers in group B are shown in Table XVIII. The lower the score, the more positively the officers felt about that aspect of the group's decision making. Thus a minimum score of one would indicate that the officer strongly agreed with all the statements in a given area (ie was positive about the group), and a maximum score of seven would indicate that they strongly disagreed with all the statements (ie was negative about the group).

	A	B	D	C
Communication	2.00	2.60	5.00	5.40
Problem Solving	1.25	3.00	2.25	5.00
Task Focus	2.75	3.25	4.00	4.50
Group Cohesion	3.40	2.20	2.80	5.00
Leadership	4.00	4.25	2.25	3.25

Table XVIII
Mean scores for each officer in Group B for each section of the Questionnaire

Table XVIII shows consistent differences between Officer A and Officer B's perceptions of the group decision making. Whilst Officer A was extremely positive about the way the group made the decision, having the lowest mean scores for problem solving and task focus, Officer C consistently rated the group as having been inadequate in these areas. Officer A was very positive about the way the group had gone about the decision, reporting that the group had clearly focused objectives and had thoroughly considered a wide range of alternatives. The mean score for officer A's response to the problem solving items is 1.25. Whilst officers B and D were somewhat less positive about the group's problem solving strategies, officer C believed that they had been neither systematic nor broad in their consideration of the links between the incidents. The mean score of 5.00, shown in table XVIII reflects this.

Similarly, Officer C believed that his views had not been represented in the decision, whereas Officer A felt very positive about his input to the decision. This is reflected in their actual input, Officer A having all 12 of his links represented in the decision, and Officer C having only two of his initial links taken into consideration. Officer C also rated the group particularly badly in terms of their cohesion.

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In this respect then, the police officers' response to the questionnaire has been shown to reflect their input to the final decision. However, whilst there is some relationship between the number of their original links which are represented, emphasis must also be placed on the processes within the group. Thus for example whilst officer A (all twelve links represented) is consistently more positive about the group than officer C (two links represented), officer B also rated the group positively even though only one of his original links was finally represented in the decision. It is important to note that Officer B supported Officer A's views during the group discussion, and was therefore quite satisfied with the group's decision despite the lack of representation of his original views on the decision problem. This emphasises the need to consider closely the way in which the structure and influence of the group affect people's perceptions of the decision.

In order to examine the group members' perceptions in more detail the officers' response to two sections of the questionnaire, communication and leadership, were analysed using Partial Order Scalogram Analysis (POSA).

6.8.2 Partial Order Scalogram Analysis

The data from the shortened questionnaire for all twenty-four police officers who took part in the study was analysed using Partial Order Scalogram Analysis (POSA). (For a more detailed description of the application of POSA to the questionnaire data see Chapter Four). Each member of the group is shown on the plot according to their views on each of the different areas and is represented by a letter. The other points in the plot represent officers from other groups.

Two separate POSA plots of the police officers with respect to their response to the two sections of the questionnaire are shown in Figures 9 and 10. The way in which each questionnaire item partitions the plot is summarised so that the further the point is plotted in the direction of the arrow, the more the officer agreed that the statement was characteristic of their group.

Leadership

The plot relating to the participants' perception of the extent of leadership is shown in Figure 9. This plot shows that there is very little distinction made by the police officers in terms of the extent to which their leader encouraged them to express their views (partitioning the joint axis). On the other hand across all the officers who took part in the study, the full range of responses to the statements 'The group developed a clear leader', 'The group's decision was influenced by a dominant leader' were elicited, and are represented along the y axis. Orthogonal to these are the responses to the statement 'The group would have benefitted from a good leader', partitioning the x axis. This statement clearly contains some ambiguity as a group with no leadership could benefit from a good leader as could a group with a bad leader.

However, the lack of variation across the whole plot indicates that with increasing clarity of leadership (on the y axis) the less likely the officers are to say they needed a good leader. The one unusual exception to this comes from the opinions of Officer 'D' who's opinions are

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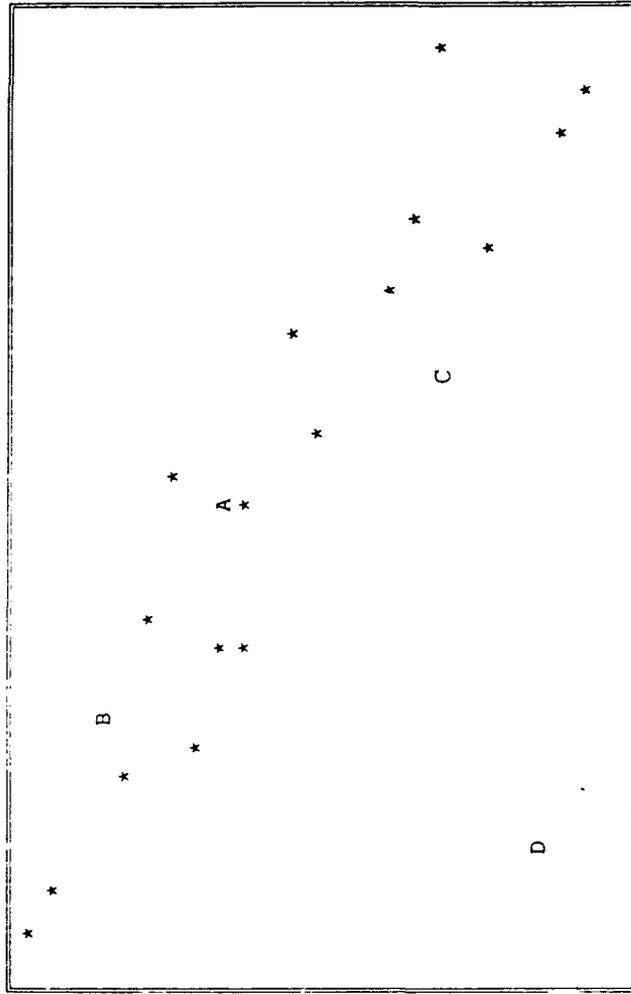
The group would have benefitted from a good leader.

Figure 9. POSA Plot of all Participants in the Police Decision Making Group According to their Response to Leadership Items on the Questionnaire. Members of Group B are shown as Letters. Partition Orders for each Statement are Summarised.

The group developed a clear leader.

The group's decision was influenced by a dominant leader.

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quite clear. In her opinion, a dominant leader emerged in the group, yet they still required a good leader.

Communication

The POSA plot for communication items (Figure 10) clearly shows that DI 'A' and the officer who backed him (DI 'B') were extremely satisfied with the extent to which their views had played a role in the decision. The mean scores on these items were 2.00 and 2.60 for officers A and B respectively. Officer 'A' had all twelve of his links represented. However, since detective 'B' only had one of his links represented it is clear that this measure of a person's contribution is not an accurate predictor of their satisfaction with the group. Clearly officer 'B' changed his original views to support officer 'A' and was therefore quite satisfied that his opinions were represented.

On the other hand officers C and D were far less satisfied that their views had been heard and were more likely to believe that the decision had been dominated by 'certain individuals'. Officers C and D's mean response to the communication items were much higher than those of officers A and B, indicating that they were more negative about their input into the decision.

Summary and Conclusions

The results revealed by POSA are of particular interest in terms of people's perceptions of the processes of group decision making. It is clearly important to stress the difference between the strength of leadership and the effectiveness of that leadership. In the case of group B, although a strong leader emerged, not all the members of the group believed that this was beneficial to their discussion. Indeed, although the officers did not at that stage know the true solution to the decision problem. Officer A's leadership resulted in a completely inaccurate solution. The results of the MSA presented in Section 4.7 have shown that a combination of their original views would have been considerably more accurate than the result obtained following the discussion.

It is therefore particularly important to address the issue of group processes and to consider the way in which certain individuals, whether by way of status or perceived knowledge can influence the group decision making. It is also of interest to consider the relationship between perceptions of leadership and communication in this group. Officer A's perceptions of his input to the decision have objective backing, his views were certainly heard by the group and represented in the decision. Likewise Officers C and D did not have much input to the decision and their perceptions reflected this. On the other hand, Officer B's positive assessment of his communication appears to reflect his belief in Officer A and the approach he was taking rather than an objective assessment of his own input to the decision making group. Further, whilst officers A and B felt that their views were represented, they also believed that everyone's views had been considered although clearly C and D felt otherwise. The group's perception of leadership further illustrate the way in which perceptions of the group may be distorted.Whilst officer D strongly agreed that a clear leader had emerged, officer A and B either did not recognise or were unwilling to acknowledge A's dominant role in their discussion.

Certain individuals dominated the discussion (R)

All of my views were represented in the decision

The group allowed me to express all of my views

Some of my ideas were not taken into consideration in the final decision. (R)

I found it quite difficult to get my views heard. (R)
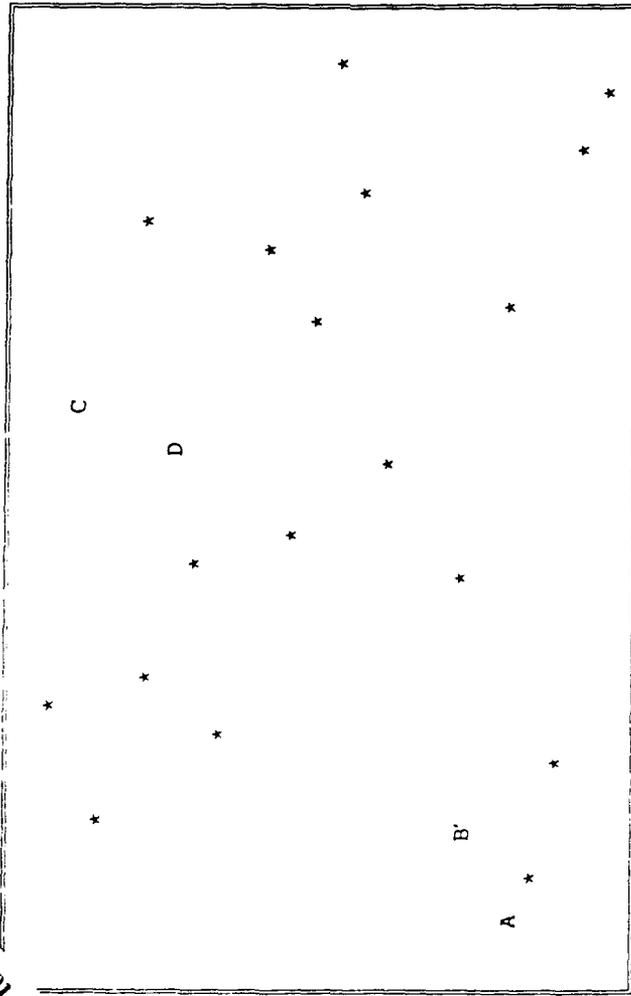
Figure 10. POSA Plot of all Participants in the Police Decision Making Group According to their Response to Communication Items on the Questionnaire. Members of Group B are shown as Letters. Partition Orders for each Statement are Summarised.

(R) = Reverse Coded

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In conclusion, this example has shown the importance of considering group processes, and their effect on decision making. It is essential to understand the way in which processes can distort the group's decision and to develop the decision support system in such a way that groups can be aware of their possible adverse influences.

The results have shown how close the group can be to an accurate solution on the basis of a logical combination of their views before they unleash the affects of group processes. It is essential that the proposed system does everything possible to ensure that the results of expert communication be beneficial rather than detrimental to the outcome of decision making.

CHAPTER 6: APPENDIX A

THE VICTIM STATEMENTS

Incident 1

I felt a hand come across my face and his other hand came across my throat. The he took his hand away from my mouth and turned me round. At this time I was crying and I asked him to leave me alone, but he kept telling me to shut up. He then said 'Do you want me to hit you ?' I said 'no'.

He then told me to take my top off. I said no. He kept telling me to take it off and I kept saying no. He then told me to lift my arms up and he pulled my top and my bra over my head. He then undid my trousers and pulled them down to my ankles.

He then told me to lie down, which I did. He then told me to turn round. When I turned round he was on his knees and he had his thing out. He then said 'suck it'. I said no. He then layed on top of me. He then told me to open my legs and I said no. He then said something like 'do you want me to kill you '

He then got on top of me and pushed my legs open. He then put it inside me and told me to hold him. He then asked me if I was enjoying it. I said 'No I'm scared and frightened'. He asked me what the matter was and whether I had lost all my energy.

I'm not sure whether he ejaculated or not. He then took it out. After a while he got up and I sat up and asked him if I could get dressed.

He told me not to move and warned me not to move. He asked me if I was going to tell anyone and I said no. He told me that there was only one way to make sure and that was to get rid of me.

I got up to run. He grabbed me round my mouth while I was running and told me I was a stupid bitch. The he picked me up and put me over his shoulder and started walking. He put me down and he just got up and went. I stayed for about five minutes to make sure he had gone and then I got up and ran to my boyfriends flat.

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Incident 2

He clamped his hand over my mouth. He then said to me 'Don't struggle or scream or else you'll be a dead girl.' He made me kneel with my back to him.

He kept saying 'How old are you ?' and he also kept repeating the threats about how he'd kill me. He said 'lie down' and he knelt between my legs. I was lying on my back with my face to the side. He lifted up my skirt and petticoat and then he raised me up and took my pants off. He had already undone his trousers and then he layed on top of me.

He then put his penis into me. It lasted about 3-5 minutes. He was talking to me. I remember him saying 'can you feel it' and he kept asking me whether my boyfriend was black or white. He asked me to touch him, which I did. He then came inside me. He then got off me and said 'promise me you won't tell your boyfriend or the police. If I hear from anybody that you have told anybody you will be a dead girl'.

He then said 'don't move until I've gone'. He then walked away.

Incident 3

He dragged me backwards telling me not to struggle. I was
screaming trying to make someone hear me. The man said 'One
more word and I'll cut your throat'. He told me to lie face
down which I did. He climbed on top of me with his knees
straddling my legs. He lent forward and grabbed both my arms
and pulled them behind my back. I could feel that my bottom
was exposed.

He said 'You've done this a lot before havent you'. I said no.
He then moved down my body and back up slightly. I could feel
his penis on my bottom. I could feel him trying to part my
legs with his hands and then I felt him take hold of his penis
with his right hand and he forced it into my vagina. He
started to move backwards and forwards inside me very slowly.
I couldn't feel him lying heavy on me and so I think he was
supporting himself with his hands although I couldn't see
them.

About thirty seconds after he started having intercourse with
me he gave a slight gasp and he stopped and got off me. The he
just walked away without saying or doing anything else.

Incident 4

He grabbed me around the shoulders with both arms. I twisted
to try and get away. I was screaming and shouting and he said
something like 'shut up or it will be worse.'

I don't remember how he took my jumper off but I remember him
pulling my cotton camisole top off and he took off my skirt
and pants. He pulled me straight so that I was lying on my
back. He undid his trousers and pulled them down to his hips.
He tried to put his penis inside me but I don't think he put
it right in. He knelt back up and said 'put it in your mouth,
get down on it' He pulled me by the hair towards his penis
which was erect. I kept saying 'I can't' and he pulled my head
down onto his penis and forced me down onto it. He said 'If
you bite it I'll kill you.' Then he ejaculated straight away
into my mouth. He got up and did his trousers up.

He asked me for my name and address. He took some things out
of my bag and said 'what's your address, if anything happens,
if you report me, I'll come and get you'.

He just got up and walked away. I picked up my bag and ran.

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Incident 5

By this time I was lying face down and I had no clothes on. I asked him what he was going to do and he said 'what do you think I'm going to do ?' He then touched my bottom with his hands and he parted my legs by pushing my knees apart. He then placed his erect penis in my vagina and had intercourse with me. During this he asked about the size of my bust and he commented on the fact that they were soft.

The intercourse lasted about five minutes. Then he stopped and he left.

Incident 6

He pushed me down onto the ground from my front using his hands to push my shoulders down. I fell back easily onto my back. I looked up at him and he was kneeling over me. My legs were stretched out but slightly bent.

He undid the flies of his jeans and opened them up but he didn't pull them down.

He lifted up my skirt and pulled my knickers right off over my shoes. When he pulled my knickers off he pulled me up towards him so that I was sitting up facing him. Somehow, I don't remember exactly, he managed to put his hands under my blouse and pull my vest type bra over my head so it was twisted behind my head.

I think his jeans had slipped down to his lower thighs. He pulled my head down. He was holding my head firmly. He kept saying 'suck it. suck it'. I knew he meant this to be his penis and he made me have oral sex with him. He kept thrusting it into my mouth deeper and I felt sick. He then ejaculated inside my mouth. He took his penis out of my mouth.

He said quietly to me 'Don't scream or I'll break your neck and I can do.' We both stood up, he didn't help me up. Then he pushed me back down onto my back. He was down on his knees and he forced with his hands my legs open at the knees. He said 'Where is it, where's your minge, what's wrong'. I said something like 'I'm too frightened'. His penis was erect and he pulled me onto his penis with my legs open he put his penis into my vagina. He leant over me with my legs still apart and his legs between me. He wasn't in me for very long.

I don't know how it ended but he got up and pulled his trousers straight.

He said 'can I trust you'. I said 'Yes you can trust me'. He said 'If you tell anyone and they come round to my door I'll find you again'. We both started walking away. I looked around and then I started running.

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Incident 7

A hand came round from behind me covering my nose and mouth. He said something like 'take your jeans off'. He something about if I didn't do what he said he would hit me.

Then he just pulled my jeans and they just fell to pieces because they were old ones. I think he noticed that my underpants hadn't fully come away and then he pulled them off me.

The next thing I realised I was lying on the floor on my back. All the while he kept talking saying that he would hit me, it would be easier for me if I didn't continue fighting him.

He then knelt in between my legs and pulled his tracksuit bottoms down. His penis was erect and he forced it into my vagina.

He then got up and stood behind me. He told me not to talk to anybody. He asked me previously where I lived and I told him the area. Then he left.

Incident 8

He grabbed me from behind. He said 'be quiet or I'll cut your
throat'. He said 'undo your coat and take your trousers down.'
I did this and he said 'and your knickers'. I hesitated at
first and then he said 'I'm going to cut your throat if you
don't and I will.' He said get down on the floor. He said 'lay
down'. He had already undone his trousers.

I layed down on the ground and he got on top of me. He said
'Put it in'. I didn't move. He pushed my legs apart and he
tried to push his penis into my vagina. He pushed harder and
his penis went inside me.

He moved up and down very slowly. I can't remember how many
times he moved up and down. He got up and then he walked off.

Incident 9

He pulled me down to the ground. I fell backwards down to the ground and landed on my back. He knelt over me with his legs either side of my right leg. He held me down and with his right hand he tried to pull my trousers down. He tried to pull my tights off. He pulled my trousers over my shoes and then started pulling at my knickers. He then started to pull up my jacket and jumper with both hands. He pulled them up my chest and also pulled up my bra so that my breasts were showing.

He then lay on top of me and I could feel his penis against the outside of my vagina. He must have unzipped his trousers at some point but I hadn't noticed. He pulled me over so that I was lying face down and tried then to push his penis into my vagina.

He then turned me back over so that I was lying on my back and he tried again. He pulled my head up with his left hand and said 'suck this'. He tried to pull my head closer to his penis. He then put his erect penis into my mouth. I felt sick. He didn't do this for very long.

He then lay back on top of me and pushed his erect penis inside my vagina. He started to move his penis in and out of me quite quickly. I could hear him breathing quickly and making groaning noises. He ejaculated quite quickly and he immediately took his penis out of me and stood up. I heard him zip his trousers up and when I opened my eyes I saw the man walking away from me.

Incident 10

He put his arms round my neck and pulled me down.

He then said 'kiss me' and I tried to push him away and he pulled me to the ground.

He lifted my skirt and he was on top of me. He then started pulling my tights down. He pulled my tights and panties off completely. He undid his trousers and got back on top of me and had sex with me.

He stood up and pulled me up and told me to suck him. I said 'No' and he said 'Just do it'. He pushed me to my knees. Because I was afraid I sucked him.

I said 'Can I go now ?' He said no take everything off. I said no what for, and he said 'Just take it off'. He started to pull up my jumper and undo my skirt. Then he just stood there for a minute. I started to run off and he ran after me and pulled me down. He said 'I think I should kill you'. He started having sex with me again. After, he told me to get up and get dressed. I did and then I picked up my bag and ran.

Incident 11

All of a sudden an arm grabbed me round the throat. I was struggling to get away and he became very angry and said 'do you want to live or die ?' He then said 'lie down' which I did. He then pulled down my tights and panties at the same time.

He got on top of me but he didn't have his whole body lying on me. 1 felt his penis inside me. He said 'show me what you can do'. I said I can't do anything. He said 'lift your bottom up, come on you must show me something.'

He said 'I don't want to see anything in the papers about this otherwise I'll kill you'.

He stood up and I heard what sounded like an adjustment of clothing. He went and I heard him running away.

Incident 12

He pushed my shoulder so that I was lying facing away from
him. The he said 'lie on your stomach'. I felt him lift up my
skirt and I said 'don't touch me, there's something wrong with
me I'm going to hospital next week'. He said 'shut up you
don't want me to hurt you do you. He pulled my knickers off.
''e seemed to be kneeling with his legs either side of mine.
Then I felt his penis enter my vagina. He must have been
supporting himself by his arms because I didn't feel the
weight of his body on mine.

He was only moving in me for a very short time.

I managed to move so that I could see him. He jumped up and
ran off.

CHAPTER SIX· APPENDIX B

SAMPLE OF COMPLETED FORM

Reason for similarity	Incident Numbers

Initial approach from behind.

   1   2   3   4   7   8

   10   11

X (2) Removed upper Clothing

   1   4   5   6   9   10

Oral Sex.

   1   4   6   9   10

Threats of violence post event.

   1   2   4   6

Interest in identity.

   4   7

CHAPTER SIX: APPENDIX C

DECISION MAKING QUESTIONNAIRE

The group's decision was influenced by a dominant leader.   1 2 3 4 5 6 7

The group would have benefitted from a good leader.   1 2 3 4 5 6 7

The group developed a clear leader.   1 2 3 4 5 6 7

The leader encouraged me to express my opinions.   1 2 3 4 5 6 7

Certain individuals dominated the discussion.   1 2 3 4 5 6 7

We had enough information to make the decision.   1 2 3 4 5 6 7

We could have done with more focus on the task in hand.   1 2 3 4 5 6 7

The group got involved in irrelevant discussion.   1 2 3 4 5 6 7

All the possible solutions were given consideration.   1 2 3 4 5 6 7

A wide range of alternatives were explored.   1 2 3 4 5 6 7

The group had clearly focused objectives from the start.   1 2 3 4 5 6 7

The group allowed me to express all of my views.   1 2 3 4 5 6 7

The group worked together very efficiently   1 2 3 4 5 6 7

I really liked working with this group   1 2 3 4 5 6 7

All of my views were represented in the decision   1 2 3 4 5 6 7

I enjoyed the group discussion very much   1 2 3 4 5 6 7

Evaluation of the solutions was done in a
very systematic way.   1 2 3 4 5 6 7

The discussion was focused on the problem in hand.   1 2 3 4 5 6 7

Some of my ideas were not taken into consideration
in the final decision.   1 2 3 4 5 6 7

I found it quite difficult to get my views heard   1 2 3 4 5 6 7

There were several disagreements between the
group members   1 2 3 4 5 6 7

Some conflict existed between the members of the group   1 2 3 4 5 6 7

CHAPTER SEVEN:

DATA STRUCTURES: ANALYSIS OF A QUALITATIVE DATA BASE. AN EXAMPLE STRUCTURING THE BEHAVIOUR OF HIJACKERS.

It has been proposed that two forms of inference from qualitative data can be used in decision making;

> i) elicitation and representation of the knowledge of expert decision makers as part of the decision making process.

> ii) elicitation and representation of the qualitative relationships inherent in a data base to inform decision making.

The study provides an example of the latter application with respect to qualitative differences in terrorist behaviour during ariel hijack. Descriptions of behaviour in thirty skyjacks provided by Mickolous in his book 'Transnational Terrorism' were content analysed to provide twenty nine qualitative variables.

Smallest Space Analysis (SSA) of the variables revealed similarities between aspects of behaviour associated with different types of skyjackers. The representation distinguishes between aspects of skyjack associated with individuals who take an aircraft for personal reasons and those who are involved in terrorist organisations.

Using Multidimensional Scalogram Analysis (MSA) to plot the similarities and differences between a subset of sixteen skyjacks shows that on the basis of eleven key variables it is possible to distinguish clear regions associated not only with 'personal' or 'organised' incidents but also between different terrorist organisations.

The study therefore demonstrates the potential of using published sources as a basis for identifying distinguishing characteristics of terrorist behaviour. Once established such differentiations can become part of the inference process of people making decisions about terrorist activities.

Chapter Seven

Data Structures:Analysis of a Qualitative Data Base
An Example Structuring the Behaviour of Hijackers.

7.1.1 Introduction: Knowledge Inherent Within Qualitative Data

Chapters Five and Six have explained the principles by which qualitative knowledge existing in witness statements and other police material can be elicited using content analysis and represented using Multidimensional Scalogram Analysis (MSA). This work demonstrated how salient variables of sexual attacks can be used to build up a typology of behaviours.
It was hypothesised that this material could be used in the future to relate types of offense to types of offender. This kind of analysis would have a role to play in live police enquiries, for example, by suggesting links between solved and unsolved crimes, and by identifying links in serial crime.

The current work aims to expand the possible use of this type of representation in two directions. Chapter Six of the current report further develops the principles for deriving inferences from police material in a decision making situation, investigating the way that crime investigation managers could use such a representational system for decision support. The current chapter, however, addresses the potential of these principles to the structuring of qualitative knowledge in a data base, in this case the similarities and differences between incidents of terrorist activity.

7.1.2. Profiling Terrorist Activity

Whilst terrorism is certainly not a new phenomenon Wardlaw (1983) argues that aspects of technological development have led to an escalation in the potential for modern day terrorist attacks. Increased mobility, communication, publicity and sophistication of weaponry have led to an increase in violent action taken by those who for one reason or another feel that they have no other way to pursue their particular cause.

The increased incidence of international terrorism during the last two decades (Merari and Friedland 1985) brought with it a corresponding interest in who gets involved in such action and why. Parallel to the study of criminal personality types, much of this work has developed from attempts to understand the psychological make-up and psychiatric 'problems' which were assumed to underlie a person's involvement in terrorist organisations.

7.1.3 Psychiatric Variables

In the same way that typologies of sexual offenders have been developed (eg Groth 1979; Marshall 1989) there has also been much research directed towards establishing the 'types' of terrorist which may be encountered. A great deal of this work, in parallel with the profiling of other types of criminal has been described in terms of the individuals' psychological make-up. Such contributions have focused both on the individual in terms of personality disorder and on the qualities associated with the role of the player with the terrorist

organisation.

Post (1983) distinguishes two types of terrorist, anarchic-ideologues and national-secessionists, both of whom he characterises as joining a terrorist group in order to heal some kind of split, the former in the 'psyche' and the latter in the national identity. Similarly, Suellwold (1981) identifies two personality types attracted to terrorism, the extrovert attracted by the lifestyle of a revolutionary who suffers from a narcissistic personality disorder and the paranoid personality whose suspicion and aggression leads them to seek for an outlet for their hostile and paranoid feelings.

Turco (1987) considers four personality types to be found in the terrorist arena; those with inadequate personalities, those with antisocial personalities with a criminal outlook, paranoids with bizarre demands and religious overtones, the hypomaniac-depressive who he considers to be the 'suicide to be'.

Turco goes on to outline his views on the type of personality profiles expected from different roles within the terrorist organisation. He considers the Leader to be most likely to be the paranoid personality who is rigid and suspicious. They are likely to have feelings of self importance and are not amenable to logical argument.

The 'Activist or Operator' is characterised as an opportunist, with a low tolerance to frustration and a tendency to blame others. He suggests that their motivation is rooted in 'ego', in as much as their 'muscle' is needed for the operation. These individuals are likely to have considerable criminal experience.

Finally, the Idealist is characterised as the most normal member of the organisation, frequently politically naive and guilt ridden, their innocence is exploited and radicalised by the other group members. It is feelings of dependency which bring this individual to the group and they are the most expendable of the team members.

7.1.4 Demographic Variables

A second area in which the focus of characterising terrorists has been placed is in the identification of common background variables which may be associated with different members of the terrorist organisation. Certain consistencies repeatedly feature in the authors consideration of 'who' is involved and at what level.

Thomas Strentz of the FBI outlines the consistent findings of his own and a number of other authors findings in profiling a background characteristics of modern terrorists (Strentz 1988; Hacker 1976; Russell and Miller 1977).

Strentz distinguishes between the leaders and followers and those supporting left and right wing causes. He points out that whilst left wing terrorist organisation are typically involved in complex planning of operations, the right wing groups rely on stock piling of weapons and explosives. Where left wing groups get involved in the type of terrorism which requires negotiation, right wing groups typically indulge in violent attack.

In terms of the right wing terrorist organisations he believed little has changed in the type of person who has been involved over the last three decades. *Both leaders and followers are most likely to be white, male protestants who are literate in English. The leaders are typically college educated, middle class, urban sophisticated, and politically articulate.* The followers on the other hand are more likely to have limited formal education, be lower middle or lower class, be unsophisticated (urban or rural) and politically naive. Further, while the leaders are likely to have high verbal skills and a strong (if paranoid) personality, the followers are likely to have poor verbal skills and a weak personality. On the right, in contrast to members of left wing terrorist organisations, both leaders and followers are found in older age groups, as well as thirties (leaders) and twenties (followers).

The demographic profile of members of left wing terrorist organisations is particularly interesting since according to Strentz the type of people involved in these organisations has changed substantially in the last decade. The only change in the type of leader is in age range, being more likely to be slightly older than previously, and where women were as likely to lead left wing organisations as men, the present situation shows more likelihood of a male leader. These changes aside the left wing terrorist leader is likely to be middle-class, urban, sophisticated individual of no specific race or religion with a college education. These people are reported as strong personalities who have been politically active and are dedicated, multilingual, well trained and possessed of high verbal skills.

However, Strentz points out that substantial changes have occurred in the lower ranks of the left wing organisations, specifically in the middle east. The opportunist or criminal element is no longer found within the organisation and several characteristics of the followers have changed.

The followers of the sixties and seventies were essentially similar to the leaders only younger and weaker personalities. Those found in the eighties are considerably younger (17-25), predominantly male, from large lower class families, with little or no education, poor skills and training, and limited dedication. These people are likely to politically naive and have been criminally active in street gangs.

7.1.5 A New Approach to Criminal Profiling

The notion of constructing criminal profiles has been in existence for many years, and psychologists and psychiatrists have played a prominent role in the development of criminal typologies. However, such typologies are generally based on the psychological motivations of the offenders in relation to a particular crime. For example, rapists have been considered as motivated by anger and the need to express power (Groth 1979) or by intimacy and the need for social contact (Marshall 1989).

Whilst such typologies may have a role to play in the treatment of offenders in a clinical context once a criminal has been caught, as Canter and Heritage (1990) point out unless the actions taken during an offence can be related to the offender such typologies contribute little to a police investigation.

In order for profiling of criminal behaviour to have an input into actually tracing an offender

it is therefore necessary to make the link between an offender's behaviour during his criminal activity and elements of his non criminal lifestyle which could play a role identification of an individual.

The FBI has been trying to develop to more systematic approach to profiling, and a group of experienced detectives at their training centre have interviewed 36 convicted serial murderers (Ressler et al 1984), but as Canter (1989) points out their approach is still 'far more of an art than a science'(p12).

The approach taken by Canter and his colleagues at the University of Surrey uses psychological principles and methods to develop a theory of criminal behaviour. Using a variety of techniques they have been able to examine the criminal's psychological profile in a number of general areas.

Firstly, drawing on principles of environmental psychology it is possible to examine the location of various incidents in order to draw some conclusions about the way a criminal uses his own 'mental map' of an area to guide his choice of target. This carries implications for the location in which the perpetrator lives or works.

Secondly, using statistical procedures particularly suitable to large quantities of qualitative material such as the witness and victim statements from a crime and other material left or taken away from the scene it is possible to systematise the information and reveal patterns in the offender's behaviour.

Another area which has proved amenable to analysis is the development in criminal activity over time. By examining the progression in types of behaviour, choice of targets etc, in an individual's criminal history it is possible to give indications not only of the type of criminal history which should be expected in the suspect, but also to predict the future of criminal behaviour if an attacker is not caught.

In the past profiling has progressed in a rather unsystematic way, using biographical sketches of an offender's behaviour (Vorpogel 1982), or even through 'educated guesswork' (Geberth 1983). In contrast, Canter and his colleagues have begun to develop a scientific systematisation of data available following a serious crime. It is this type of systematisation and representation which holds potential for application in the study of terrorist activity.

The basic principle which has underpinned their work is that the differences between the actions and behaviours involved in attacks can be related to a particular offender. Whilst, previous work has been focused on the psychological traits expressed by offenders through their 'modus operandi', for example the need for expression of power over the victims, Canter's work takes a series of discreet actions; elements of the whole interaction between victim and offender; and examines the relationship between them as relating to that particular offender.

In this way it has been possible to produce a typology of behaviours which describe sexual attacks, and indicate four types of behaviour, sexual, criminal, intimacy and violence. Within these four broad categories fall 33 discreet behaviours. From this model it is possible to hypothesise that offenders who use one set of behaviour patterns are unlikely to use others.

For example, behaviours associated with criminality in an attack such as demand for goods and binding and gagging of a victim, are not likely to be associated with 'secondary' sexual acts which form part of the attack, for example, anal penetration and cunnilingus. Similarly, whilst some attackers use an impersonal style of attack arising from a 'blitz' attack on the victim, apologetic attackers who compliment the victim are more likely to approach the victim with some kind of confidence trick.

Once this type of model has been established it is possible to draw hypothesise links between different crimes based on the profile of behaviours used. In this way solved crimes may be linked to unsolved ones, and a number of seemingly unconnected cases can be hypothesised to be linked to one or more individuals.

The developments made in the structuring of qualitative material relevant to criminal investigation have thus far been centred on serious sexual attacks. However, it has now been possible to test this system on similar data regarding terrorist incidents.

Analysis of the elements of a terrorist incident allows the examination of aspects of the terrorists behaviour which may be associated with a particular organisation. Content analysis of the salient variables which characterise an incident produces a data set which can be analysed to reveal the frequency and relationship between various characteristics of the incidents.

7.2 The Data Base

The first aim of this pilot study is to apply the analysis principles to a sample of terrorist attacks and to systematically identify a number of variations in the actions of terrorists within a particular area. The type of incidents selected were ariel hijackings, as unlike bombings etc, there is more evidence of the personal and group approach to the crime through their behaviour. Although other types of terrorist incidents can also be analysed through the events leading up to them, the personal involvement in hijack presents a richer basis for illustrating the possibilities in applying this methodology

The data used for the analysis was taken from Mickolous' (1980) influential collection of material on terrorist incidents between 1968 and 1979. Consulting a vast selection of data sources Mickolous has put together an account of a large number of terrorist incidents and provides some analysis of the type of incident, nationality and affiliation of the terrorist organisations and their frequency of occurrence over the period of his study.

Whilst the present work is based on the descriptive accounts given by Mickolous, it is interesting to note that he has also developed a large computer based data set consisting of a number of variables of terrorist attack known as ITERATE II (Mickolous 1982).

The author has made this data base available to other researchers and indeed encourages collaborative work in order to develop cumulative research in this area. Authors such as Sandler and Scott (1987) and Corsi (1981) have both added to the ITERATE II data base and used it to test their particular theories of terrorism.

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Future work aims to link into this 'invisible college' (Mickolous 1987) in order to explore the possibilities of the representational techniques which have been developed over the last two years with respect to a much wider context of terrorist activity.

However, the following pilot investigation of terrorists attacks is drawn from brief descriptions of the incidents as reported in Mickolous' book 'Transnational Terrorism'(1980). It is intended to demonstrate the way that the representational procedures applied in the investigation of sexual attacks may be used to make inferences about terrorist incidents. It is not intended to draw conclusions about terrorism per se. In order to develop research in this area access to detailed background information, witness statements etc, would be required.

The pilot data base was created from descriptions of thirty 'successful' incidents of aerial hijack (details can be found in appendix A of this Chapter.) The concept of success in terrorism is particularly difficult to define. Sandler and Scott (1987) discuss two types of success in hostage taking incidents; logistical success and negotiated success. The former refers to those instances where the terrorists carried out the mission as planned, whereas the latter concerns the positive response to some or all of the terrorists demands. However, logistical success depends on the mission going as planned throughout the whole event. Whilst some skyjacks literally never get off the ground, being thwarted prior to take off, others are overpowered in flight and yet others stormed or tricked at an advanced stage of the mission.

Similarly, negotiated success is also open to further interpretation. Many authors have addressed the motivations of publicity and the terrorists relationship with the media (eg Rubin and Friedland 1986), and as Mickolous (1987) points out, without interviewing the terrorists themselves or the strategic planners of the whole campaign, it is not possible to gauge success in terms of simply whether or not the terrorists demands have been met.

Instances were selected for the current data base which represent the full 'scale' of successes at each point throughout the incident.

In this particular analysis the success of the terrorists is not addressed per se, but rather observable characteristics of their activity ie their apparent demands, and aspects of their negotiation style, for example, whether they are flexible over deadlines.

The incidents were selected to be as diverse as possible and vary according to the nationality of the planes, and the motives and affiliations of the terrorists. Inevitably, incidents had to be selected which gave the broadest accounts of the events. At this stage it is necessary to urge caution. The material used in this example is inadequate to give anything but an indication of the possibilities of the structuring technique. For example, some important details are missing in some of the attacks and must be coded as unknown. An example of this is where the author has not mentioned the type of weapons involved, (guns, grenades etc) although it is obvious that some form of threat was involved. Fuller accounts of the incidents would allow a more systematic analysis of the variations in the nature of the attacks.

Thus, in the same way that criminal offender profiling has been restricted by the information available from police records and witness statements, so too is the study of terrorist incidents.

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Nonetheless, the previous work has had a positive influence in illuminating the gaps in police reporting of incidents. By focusing the police attention on the type of information which is regarded as useful or not when statements are being taken, the development of the system has led to an improvement in the recording procedures themselves.

At present then, the work reported is intended to represent an indication of possible directions in this research, rather than to draw any conclusions regarding the general nature of ariel hijack.

For the initial analysis 29 variables were selected to represent as many of the characteristics of the hijacks as were available at this stage. Full details of the variables can be found in Appendix B of this Chapter. Each incident was scored for each variable as to whether it was (1) or was not (2) characteristic of the incident. The data matrix is therefore of the form;

```
Variable      V1    V2    V3.............V29
-------------------------------------------
Incident
      1        1     2     1
      2        2     2     2
      3        1     1     1
      4
      .
      .
      .
     30
```

Where 1=did occur
      2=did not occur

This data was then analysed using Smallest Space Analysis (SSA-1).

7.3 Smallest Space Analysis

Using an association coefficient suitable for dichotomous data a matrix of co relations between the twenty-nine variables was calculated. This correlation matrix was then analysed using Smallest Space Analysis (SSA-1). SSA-1 plots the variables as points in geometric space so that the distances between the points are inversely proportional to the rank order of the correlations. Thus the higher the correlation between two variables, the closer together those two points will be plotted in the space. The geometric representation is therefore plotted in the least number of dimensions required to reach an acceptable 'fit' to the rank order of correlations. This 'fit' is measured with the coefficient of alienation, and the lower this coefficient the better the fit of the data to the space.

7.3.1 Frequencies

The SSA plot, shown in Figure 1, represents the associations between different types of behaviour in hijack. Thus the closer together two variables are the more likely they are to both occur within a hijack.

Figure 1 shows the frequencies of all the variables in this particular selection of hijacks enclosed in regions. The outer region contains characteristics found in less than four of the incidents. The next region contains those characteristics which are found in five to ten of the incidents. The central area contains those aspects of the hijacks which occur between eleven and sixteen times and in the centre is the presence of guns which is reported in twenty-five of the thirty incidents.

In the centre of the plot are characteristics of the incidents which were common to the majority of hijacks. Towards the outside of the plot are those characteristics which less often occur in this sample of hijacks. For example, 'shots fired spontaneously' (V20), 'verbal restraint' (V22), and 'suicidal' (V17) occurred only twice across all of the incidents. On the other hand 'threat of damage to plane' (10) and 'Motive release' occurred in eleven and fourteen of the twenty-nine incidents respectively. It is important to note that this is not intended to represent the proportion of these activities in hijacks in general as the selected incidents were not a random sample.

This plot therefore illustrates the difference between the variables in terms of their generality in this sample of incidents. The most frequently occurring characteristic is the presence of guns, which appears to be a central requirement of hijacking in general. On the other hand, variables found towards the outer edge of the plot are those characteristics which were rarer. Thus, it is these variables which are more specific to the individual incidents. Nevertheless, these variables are not unique to one individual incident. It is the pattern of occurrence of these more specific behaviours which holds the potential for linking the incidents.

7.3.2 Types of Hijack

In addition to revealing general and specific characteristics of the hijacks the results of the Smallest Space Analysis allow an insight into the association between these descriptive variables. By examining the relationship between them in terms of their occurrence it is possible to classify types of hijack in terms of their behavioural and strategic components. Thus, the closer together two variables are in the plot the more likely they are to both be characteristic of an incident.

The proximity of the variables on the right hand side of the plot, for example, show that in certain types of hijack the perpetrators are likely to discuss their personal reasons for the hijack or their own problems, and are likely to also be suicidal. These types of hijack are associated with motives of relocation and result in the release of all the passengers on arrival at the desired location. However, the hijackers are also likely to fire shots if any attempt is made to sabotage their plans. This type of hijack is most often carried out by one or more individuals who are not associated with any particular terrorist organisation.

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SSA-1 for 29 Hijack Variables
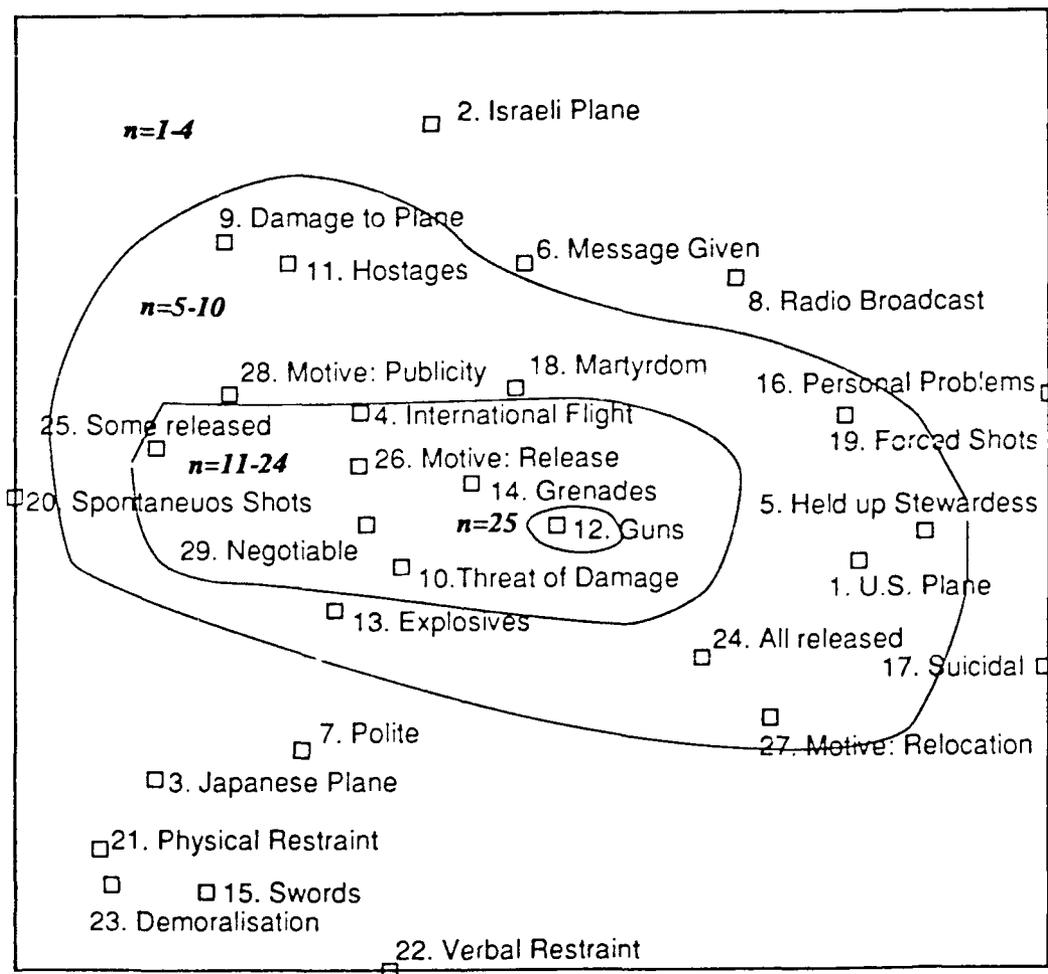
Figure 1. SSA of Twenty-nine Hijack Variables Partitioned According to Frequency of Occurrence.

Figure 2 shows the same plot with lines enclosing the variables associated with two such incidents Both of these incidents, carried out by single individuals took place on domestic flights on US planes. Both hijackers' first move was to hold up the stewardess and their reasons for the hijack were simply to travel to their chosen destination. Although the presence of guns was only mentioned in incident 30, interference in the hijackers actions resulted in shots being fired in both cases. This illustrates the difficulty of working with incomplete data. In this case it is not difficult to infer that the hijacker had a gun if shots were fired, in other more complicated analyses of behaviour connections may not be as easy to imply.

On the left hand side of the plot are those variables which are more associated with hijacks carried out by terrorist organisations. Figure 3 shows two incidents linked to the PFLP.The common features of these two incidents are taking over an international flight, the motive of obtaining release for prisoners, and the keeping of hostages after the plane has been evacuated.

Turco (1987) considers terrorists as falling into three broad categories; political-social, criminal and psychiatric. This parallels Hackers (1976) work entitled 'Crusaders, Criminals and Crazies.' According to the current. basic pilot study which we have carried out it is possible to associate the behaviours and actions which distinguish one of these terrorist types, the political-social (crusaders) from the others (see Figure 4).

The incidents represented by the characteristics on the right hand side of the plot are more difficult to describe. It is certainly tempting to describe these particular incidents are 'crazies'. However, whilst they are personally rather than politically motivated, more information would be required to distinguish the 'criminals' from the 'crazies'. This sample of incidents contained only one hijack in which the prime motivation of the perpetrators appeared to be financial gain, and it might be this type of incident which contains the clues to the behavioural differences of the criminal skyjacker.

This example has shown the way that SSA can be used to examine the relationship between the qualitative variables associated with hijack incidents. It also demonstrates that it is possible to use SSA to distinguish between the political and the personal in ariel hijack. In terms of aspects of the incidents themselves there are undoubtedly much finer distinctions which can be made between types of hijack than those demonstrated in this broad classification. Nevertheless, this pilot analysis has provided a starting point from which to develop a thorough consideration of the behaviour patterns which can be associated with different types of terrorist incidents and with different terrorist organisations.

7.4 Multidimensional Scalogram Analysis (MSA)

The SSA analysis has shown that it is possible to make a broad distinction between behaviours and motivations of terrorists involved in ariel hijack which distinguishes between the political-social and personal incidents. In order to look more closely at the differences amongst the hijacks themselves, in particular between those associated with different organisations, it is now possible to compare the incidents directly on a number of salient dimensions. For this analysis a smaller number of the incidents were selected for comparison.

SSA-1 for 29 Hijack Variables

Figure 3. SSA of Twenty-nine Hijack Variables Showing the Characteristics of Two 'Political' Hijacks.

SSA-1 for 29 Hijack Variables

Figure 2. SSA of Twenty-nine Hijack Variables Showing the Characteristics of Two 'Personal' hijacks.

SSA-1 for 29 Hijack Variables

Political   Personal

2. Israeli Plane

9. Damage to Plane

11. Hostages   6. Message Given

8. Radio Broadcast

28. Motive: Publicity   18. Martyrdom   16. Personal Problems

25. Some released   4. International Flight

19. Forced Shots

26. Motive: Release

20. Spontaneuos Shots   14. Grenades   5. Held up Stewardess

29. Negotiable   12. Guns

10.Threat of Damage   1. U.S. Plane

13. Explosives

24. All released

17. Suicidal

7. Polite   27. Motive: Relocation

3. Japanese Plane

21. Physical Restraint

15. Swords

23. Demoralisation

22. Verbal Restraint

Figure 4. SSA of Twenty-nine Hijack Variables Partitioned According to Attributes Associated with Political and Personal Hijacks.

Four incidents were selected which were known to be connected with the PFLP (Incidents 5,6,19 and 26). In addition a further four were included, which were thought to be carried out by this organisation, two of which were thought to be possible but not confirmed (17,18), and two which were thought to be connected but were denied by the PLO (9,13). A further eight incidents were included in the MSA; four incidents that were carried out by other terrorist organisations not connected to Palestinian issues (15,20,22,23) and four incidents which were carried out by individuals who were not associated with terrorist organisations (2,10,30,4).

The sixteen hijacks were classified according to eleven variables, and analysed using Multidimensional Scalogram Analysis (MSA). In this case the variables were not classified in simple yes/no dichotomies but into categorical classifications in order to maintain as much of the data as possible. The variables which were used in the analysis are shown in Table I.

The data matrix was constructed in the form below;

Variables	V1	V2	V3.....V11
Incidents			
1	1	2	
2	2	1	
3	3	1	
4	2	2	
.			
.			
.			
16			

Thus each incident is coded with a number on each of the eleven variables according to which category of that variable describes the characteristic of the incident. In this way a matrix is built up so that each incident is represented by a profile of scores across a row. This profile describes the characteristics of the incident on each of the eleven variables.

Multidimensional Scalogram Analysis then plots the incidents in geometric space so that the more similar the profiles of two incidents the closer together they are in the space. Thus those incidents which have the most characteristics in common will be closer together in the space and those which share little in common will be further apart.

Figure 5 shows the resulting MSA plot and illustrates that the incidents selected can be divided into clear regions. Whilst the plot can be divided into two clear regions according to those hijacks which were personal and those which were political, there are also clear distinctions between the terrorist organisations in terms of those known to have been carried out by the PFLP, and those by other known organisations. It is interesting to note that those incidents thought to have been carried out by the PFLP, but are unconfirmed are positioned between these two regions. Within this region a further distinction can be made whereby those incidents which were denied by the PLO are the closest to the incidents carried out by other organisations.

Consideration of the 'item plots' shown in figures 6 to 16 allows an insight into the role

Table 1 Variables used in MSA.

Variable One: Number of Hijackers

1= One person
2= Two or Three people
3= Four or more people

Variable Two: Nationality of the Plane

1= American
2= Japanese
3= European
4= Israeli
5= Other

Variable Three: Type of Flight

1= Domestic
2= International

Variable Four: First Move

1= Held up stewardess
2= Other/Unknown

Variable Five: Damage

1= Deliberate Damage to plane
2= No damage to plane
3= Threat of damage to plane

Variable Six: Hostages

1= Hostages kept on ground
2= Hostages not kept/not applicable

Variable Seven: Personal Problems

1= Personal problems discussed
2= No personal discussion/unknown

Variable Eight: Shots fired

1= Shots fired when forced
2= Shots fired spontaneously
3= No shots fired.

Variable Nine: Release of passengers

1= All passengers released
2= Some passengers released
3= Other

Variable Ten: Primary Mouve of Hijack

1= Release of prisoners
2= Relocation
3= Publicity
4 =Money

Variable Eleven: Negotiation

1= Negotiable
2= Not negotiable/not applicable

MSA on 16 Hijacks for 11 Variables
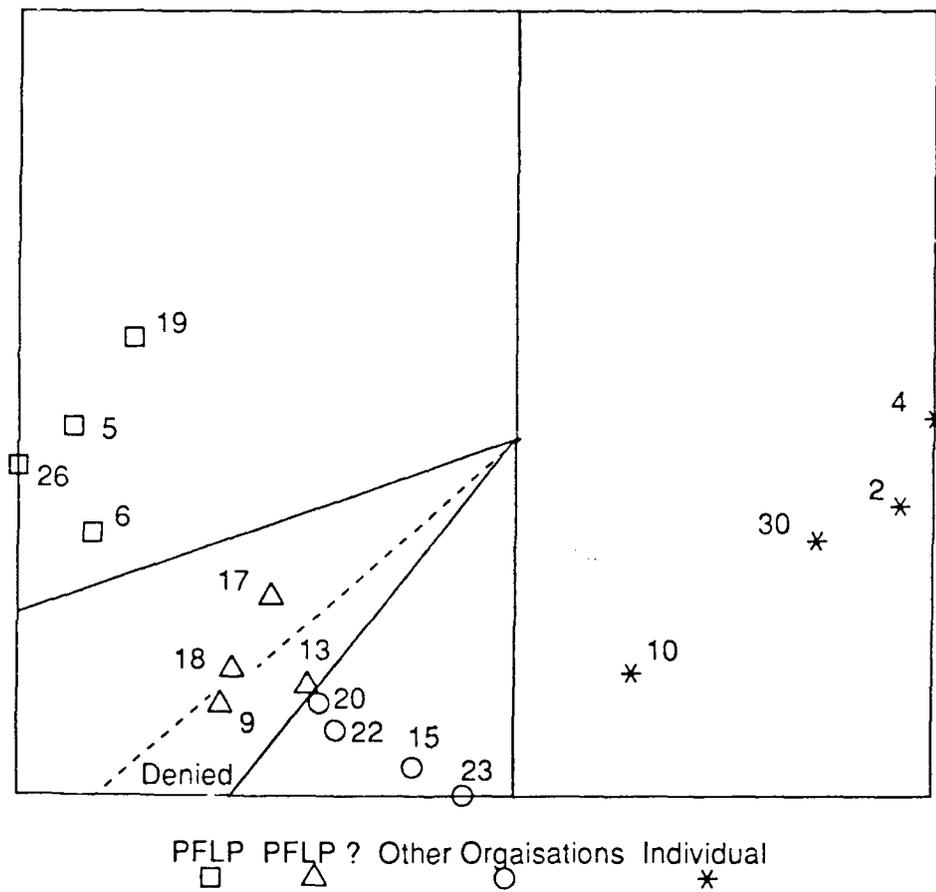
Figure 5. MSA of Sixteen Hijacks According to Eleven Attributes, Partitioned According to the Affiliation of the Hijackers.

played by each variable in distinguishing between the incidents. Figures 6 to 16 show the same configuration of points, each figure representing the classifications of the incidents on each of the eleven variables. The plot is divided into regions which show which of the incidents possessed each characteristics. Comparison of the regions on each of these 'item plots' shows how combinations of characteristics can be seen to characterise the incidents.

Those incidents which were carried out by individuals who were not connected to any terrorist organisation fall into a number of overlapping regions on the right hand side of the MSA plots.

These incidents all occurred on domestic flights (Fig. 6), and although shots were fired in all the four cases they were in response to some action taken by the airline staff or security forces (Fig. 7). The incidents did not involve any hostages being taken following the incidents (Fig. 8) and there was no threat of or actual damage to the plane (Fig. 9).

The motivation for most of the 'personal' hijackings was to travel to a specified destination (Fig. 10), although one of the incidents involved the demand of a large sum of money. During three of the four incidents the hijackers talked of their own personal problems (Fig. 11). Three of the four incidents were carried out by a single individual and their first move was to hold up the stewardess (Figures 12 and 13 respectively).

This confirms the pattern which distinguishes between the 'personal' hijackings and those associated with terrorist organisations. However, it is particularly interesting to consider the incidents carried out by the different terrorist organisations. When the similarities and differences between the incidents are taken across all eleven variables a clear scale is revealed. At the top left hand side of the plot are those incidents known to have been carried out by the PFLP. This is followed by those thought to be attributable to the PFLP, and those thought to have been but which were denied. Finally, there is a group of incidents known to have been carried out by other terrorist organisations.

In contrast to those incidents of a personal nature all of the incidents carried out by terrorist organisations did not contain any reference by the terrorists to their own problems. In addition, all but two of the non personal hijacks were reported as being motivated by overtly political aims, that is for the release of prisoners or for publicity of their particular causes.

With respect to distinguishing between the different terrorist organisations, the hijacks known to have been carried out by the PFLP in this sample were all of international flights, as are three of the four suspected to be connected to this organisation. However, none of the 'personal' hijackers or those from other organisations took over an international flight. It could be hypothesised that the increased organisation required to hijack an international flight deters the 'amateur' or those from smaller terrorist groups.

It is interesting to note that although most hijackers carry guns, few in the present sample used them. In particular, only two of the hijacks were characterised by shooting which was not a direct response to an attempt to thwart the hijack. Unnecessary violence is considered by some authors to be detrimental to the hijackers', prompting outrage and discouraging public identification with the hijackers' cause (Corsi 1981; Laqueur 1977).

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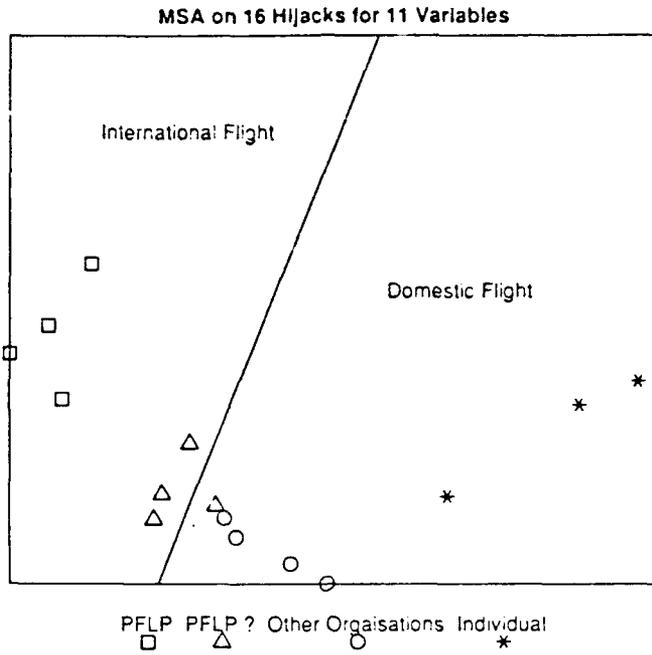
Figure 6. MSA of 16 Hijacks Partitioned According to Type of Flight.
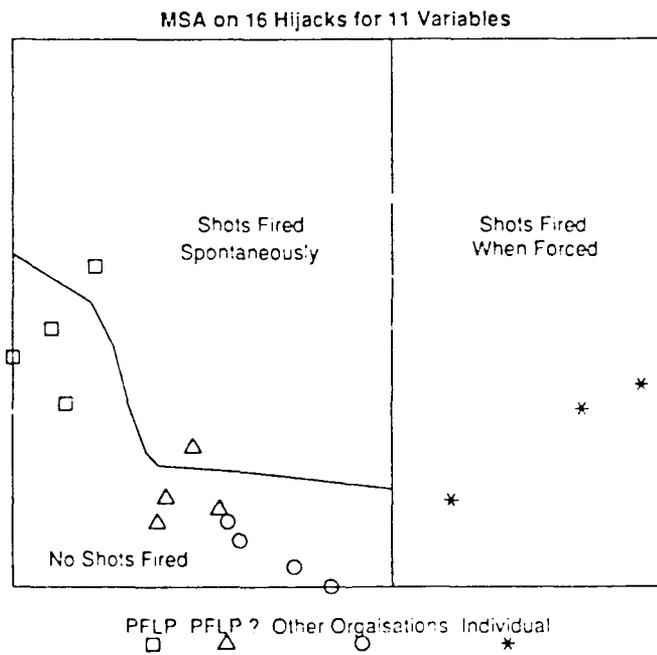
Figure 7. MSA of 16 Hijacks Partitioned According to Shots Fired.

MSA on 16 Hijacks for 11 Variables

Hostages Kept Following Incident

No Hostages Kept Following Incident

PFLP PFLP ? Other Orgaisations Individual
□   △   ○   *
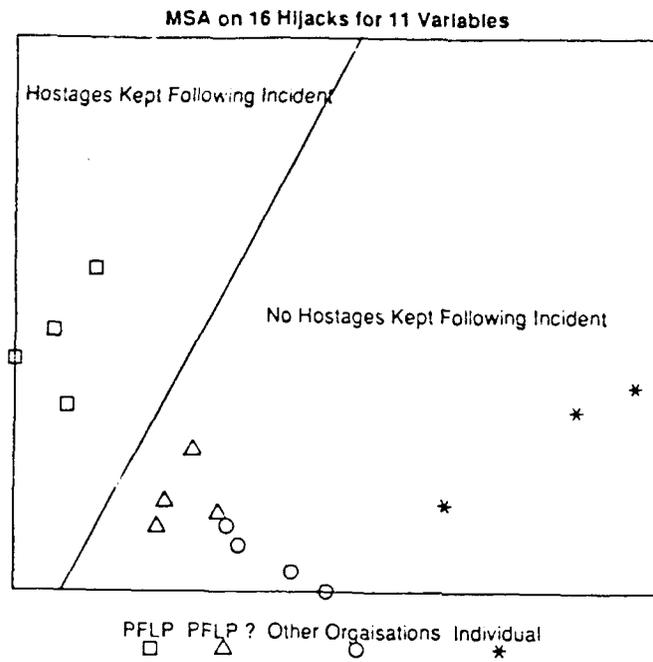
Figure 8. MSA of 16 Hijacks Partitioned According to Hostages Taken.

MSA on 16 Hijacks for 11 Variables

Deliberate or Threatened Damage to the Plane

No Damage

PFLP PFLP ? Other Orgaisations Individual
□   △   ○   *
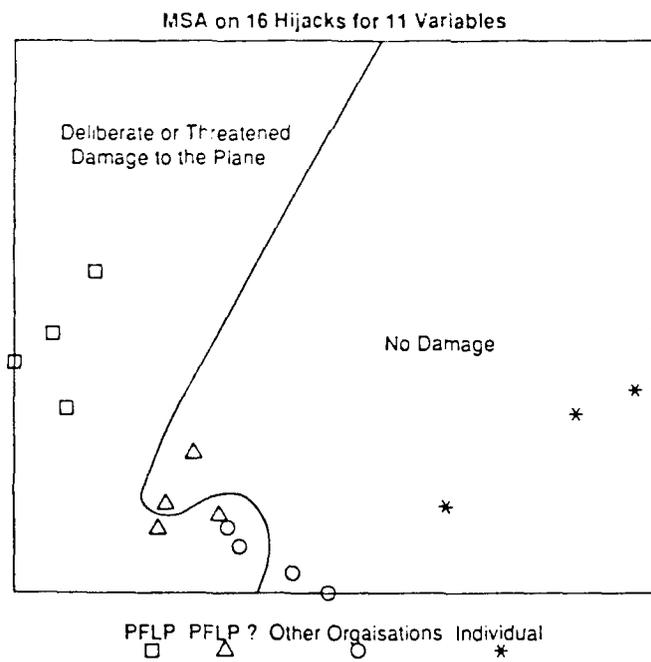
Figure 9. MSA of 16 Hijacks Partitioned According to Damage to Plane.

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Prime Motivation:
Release of Prisoners

Prime Motivation:
Money

Prime Motivation:
Relocation

Publicity

PFLP   PFLP ?   Other Orgaisations   Individual
  □   △   O   *
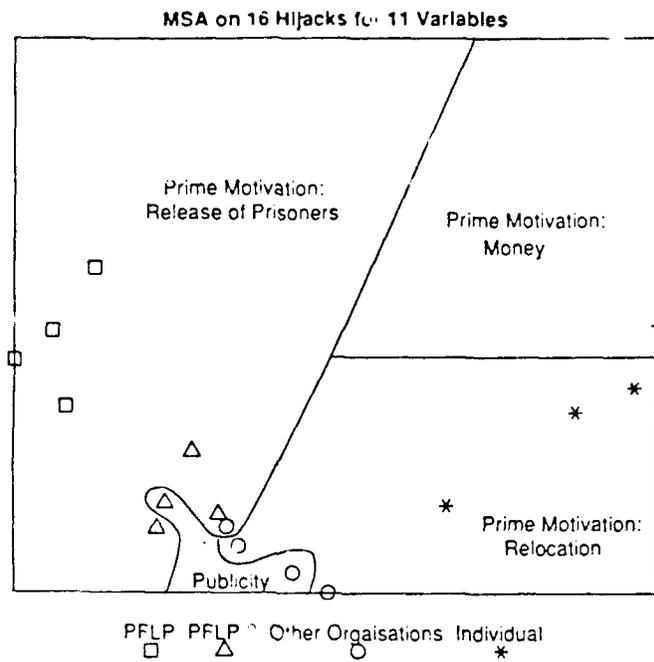
Figure 10. MSA of 16 Hijacks Partitioned According to Apparent Motivation.

MSA on 16 Hijacks for 11 Variables

No Personal Problems
Discussed

Personal Problems
Discussed

PFLP   PFLP ?   Other Orgaisations   Individual
  □   △   O   *
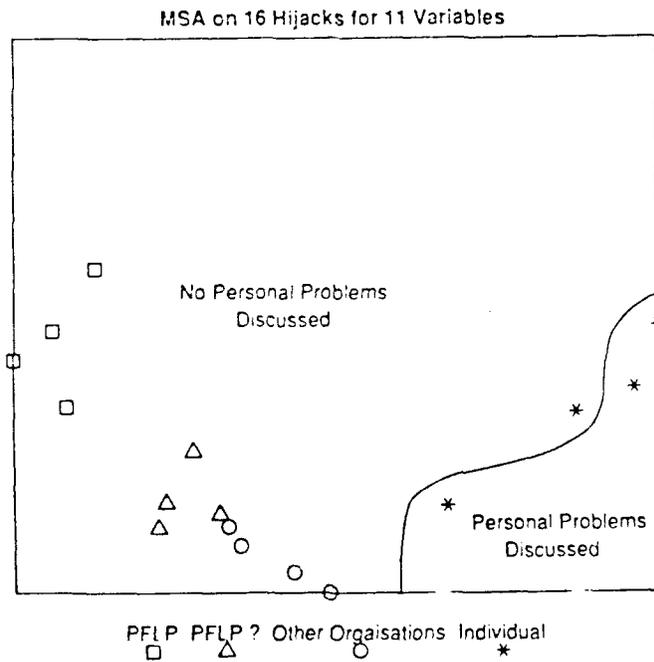
Figure 11. MSA of 16 Hijacks Partitioned According to Personal Problems Discussed.

MSA on 16 Hijacks for 11 Variables

One Person

Two or Three People

Four or More People

PFLP   PFLP ?   Other Orgaisations   Individual
□   △   ○   *
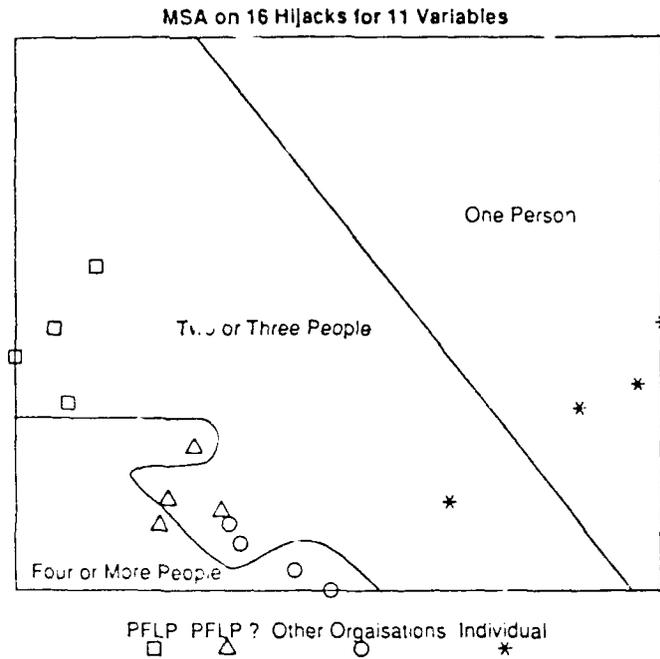
Figure 12. MSA of 16 Hijacks Partitioned According to Number of Hijackers.

MSA on 16 Hijacks for 11 Variables

Held up Stewardess

First Move Other/Unknown

PFLP   PFLP ?   Other Orgaisations   Individual
□   △   ○   *
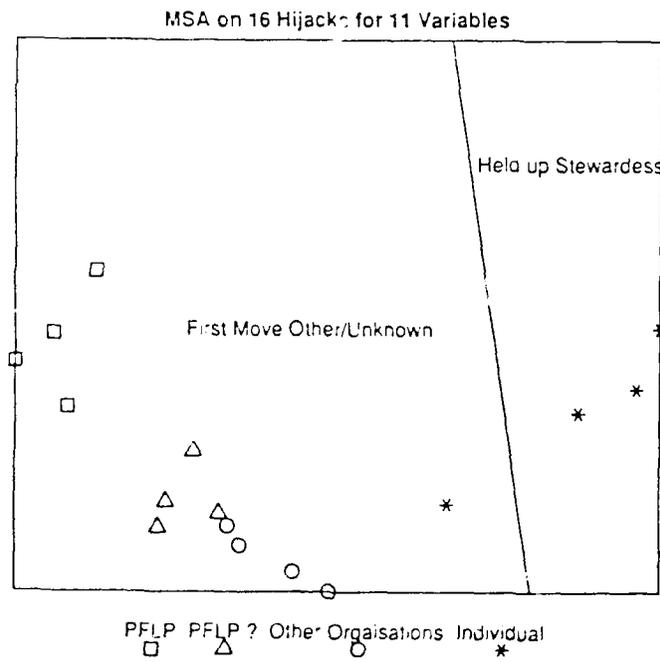
Figure 13. MSA of 16 Hijacks Partitioned According to First Move.

MSA on 16 Hijacks for 11 Variables

Israeli Airline

American Airlines

European Airlines

Japanese Airline

Other Airlines

PFLP   PFLP ?   Other Organisations   Individual
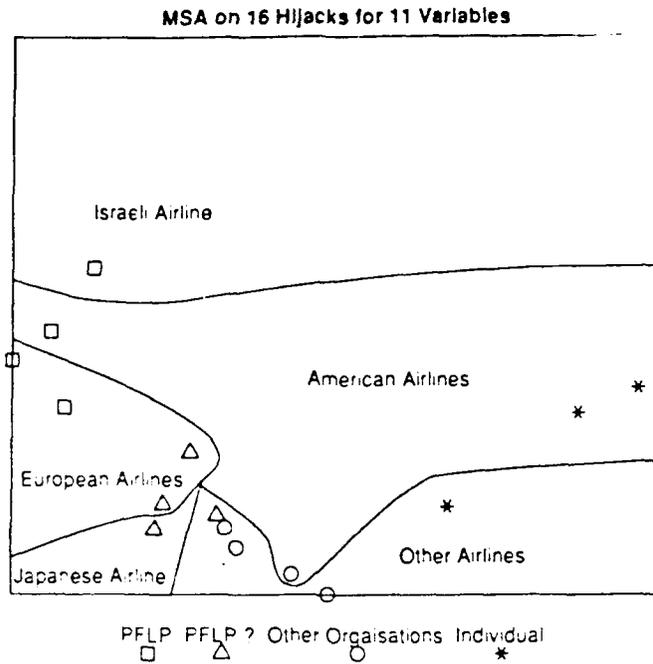
Figure 14. MSA of 16 Hijacks Partitioned According to Airline.

MSA on 16 Hijacks for 11 Variables

Not Applicable

Some Passengers Released

All Passengers Released

PFLP   PFLP ?   Other Organisations   Individual
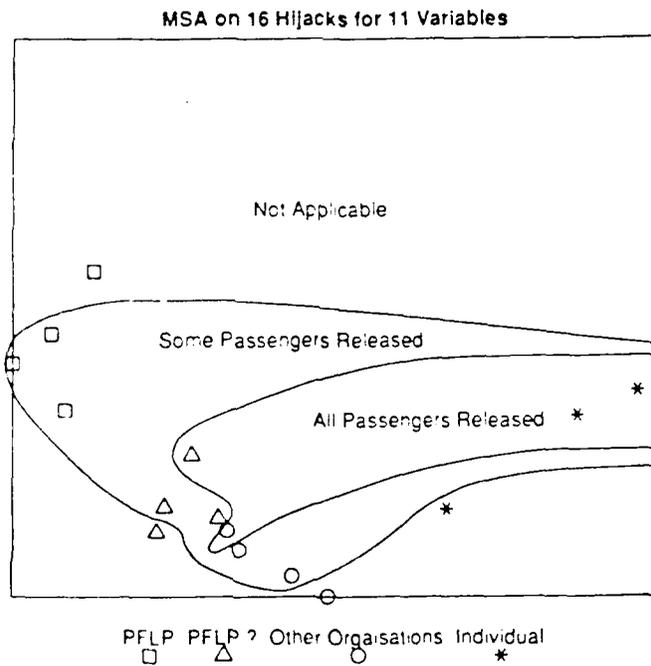
Figure 15. MSA of 16 Hijacks Partitioned According to Passenger Release.

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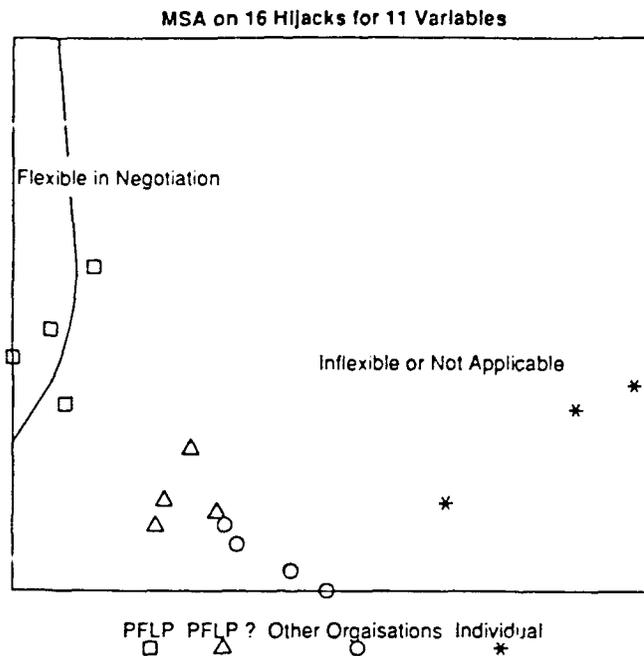
Figure 16. MSA of 16 Hijacks Partitioned According to Flexibility.

In all the incidents known to be associated with the PFLP hostages were removed from the planes on landing and kept elsewhere as part of the negotiation process. This strategy is one in which the terrorists gain some advantage as holding hostages in a surrounded position gives the authorities an advantage compared to those incidents in which the hostages are kept at an unknown location as in kidnap (Corsi 1981).
The four incidents thought to be connected with the PFLP did not follow this pattern.

In all the political incidents there was either no report of the first move of the terrorists once on board the plane, or some other first strategy was employed such as delivering a note or moving into the cockpit. None of the reports however mentioned the terrorists holding up a stewardess. If more comprehensive details of the incidents were available, it may be of importance to consider consistencies in detailed behaviour such as this.

All of the incidents known to be carried out by the PFLP were undertaken by small groups of two or three people. Of the other political attacks, half were carried out by two or three people but half were carried out by four or more. Two of the incidents which were unconfirmed with respect to the PFLP were carried out by four or more people, which is uncharacteristic of the confirmed PFLP incidents in this sample.

, 'l of the incidents known to be connected with the PFLP and two of the suspected incidents involved threat of or actual damage to the plane. However, whilst the actual damage done depends on the opportunities the terrorists have, the motivation for the damage is perhaps more important. For example, in those incidents in which the PFLP destroyed the plane it was clearly damage to property which was the motivation, the passengers having been evacuated. In the case of threats of damage it would therefore be necessary to distinguish in future work between those who threaten life and those who threaten property. This type of more finely

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grained distinction needs to be examined in much more detail for the profiling of terrorist activity.

7.5 Summary

The analysis has shown that the 'knowledge' existing in a data base can be elicited through content analysis and represented using two techniques, Smallest Space Analysis (SSA-1), and Multidimensional Scalogram Analysis (MSA).

Smallest Space Analysis represents the relationships between the variables, or in this case the characteristics of the hijacks. Multidimensional Scalogram Analysis represents the relationship between the instances (hijacks) with respect to a number of qualitative attributes. Both representations show that even using such limited materials as available for this pilot study, it is possible to visually represent different types of hijack in terms of aspects of the hijackers' behaviour. Personal and political hijacks are distinguished in addition to political hijacks carried out by different organisations.

The study therefore illustrates the potential of the methodology for analysis of the attributes of terrorist crimes. It is envisaged that such representations could be used not only for linking incidents but for examining the development of terrorist behaviour over time.

CHAPTER 7: APPENDIX A

DETAILS OF HIJACK INCIDENTS

Incident Number 1.

Date: 29.8.69
Airline: TWA
Departure Point: Los Angeles   Destination: Tel Aviv
Outcome: Plane Destroyed in Damascus
Terrorist Affiliation: PFLP

Incident Number 2.

Date: 1.11.69
Airline: TWA
Departure Point: Baltimore   Destination: San Francisco
Outcome: Hijacker escaped from Rome airport, later recaptured.
Terrorist Affiliation: None.

Incident Number 3.

Date: 31.3.70
Airline: JAL
Departure Point: Tokyo   Destination: Fukuoka
Outcome: Hijackers deplaned North Korea.
Terrorist Affiliation: JURA

Incident Number 4.

Date: 4.6.70
Airline: TWA
Departure Point: Pheonix   Destination: St. Louis
Outcome: Hijacker overpowered
Terrorist Affiliation:None

Incident Number 5.

Date: 6.9.70
Airline: TWA
Departure Point: Frankfurt   Destination: New York
Outcome: Hijackers deplaned in Jordan
Terrorist Affiliation: PFLP

Incident Number 6.

Date: 6.9.70
Airline: Swissair
Departure Point: Zurich   Destination: New York
Outcome: Hijackers deplaned in Jordan. The plane was destroyed.
Terrorist Affiliation: PFLP

Incident Number 7.

Date: 6.9.70
Airline: Pan Am
Departure Point: Amsterdam   Destination: Not Available
Outcome: Hijackers deplaned in Cairo. The plane was destroyed.
Terrorist Affiliation: PFLP

Incident Number 8.

Date: 7.9.70
Airline: El Al
Departure Point: Tel Aviv   Destination: New York
Outcome: Hijackers overpowered in flight
Terrorist Affiliation: PFLP

Incident Number 9.

Date: 20.7.73
Airline: JAL
Departure Point: Paris   Destination: Ankorage
Outcome: Hijackers deplaned in Libya. The plane was destroyed.
Terrorist Affiliation: JRA ? PFLP ? PLO etc denied.

Incident Number 10.

Date: 15.10.70
Airline: Aeroflot
Departure Point: Batumi   Destination: Sukhenni
Outcome: Hijackers deplaned Turkey
Terrorist Affiliation: None

Incident Number 11.

Date: 3.5.72
Airline: Turkish Airlines
Departure Point: Ankara   Destination: Istanbul
Outcome: Deplaned Sofia, Bulgaria.
Terrorist Affiliation: TPLA

Incident Number 12.

Date: 27.6.76
Airline: Air France
Departure Point: Tel Aviv   Destination: Paris
Outcome: Plane stormed in Entebbe, Uganda.
Terrorist Affiliation: PFLP

Incident Number 13.

Date: 23.8.76
Airline: EgyptAir
Departure Point: Cairo   Destination: Luxor
Outcome: Plane stormed in Luxor.
Terrorist Affiliation: Abel Nassar/? PLO denied.

Incident Number 14.

Date: 10.9.76
Airline: Indian Airlines
Departure Point: New Delhi   Destination: Bombay
Outcome: Hijacker drugged, Lahore, Pakistan
Terrorist Affiliation: None/? (Libyans)

Incident Number 15.

Date: 10.9.76
Airline: TWA
Departure Point: New York   Destination: Chicago
Outcome: Surrendered in Paris
Terrorist Affiliation: CNLF

Incident Number 16.

Date: 28.9.77
Airline: JAL
Departure Point: Paris   Destination: Bangkok
Outcome: Surrendered Algiers
Terrorist Affiliation: JRA

Incident Number 17.

Date: 13.10.77
Airline: Lufthansa
Departure Point: Mallorca   Destination: Frankfurt
Outcome: Plane stormed Mogadishi, Somalia.
Terrorist Affiliation: PFLP ?

Incident Number 18.

Date: 7.9.79
Airline: Alitalia
Departure Point: Tehran   Destination: Rome
Outcome: Surrendered in Tehran
Terrorist Affiliation: ? PLO ?

Incident Number 19.

Date: 27.7.68
Airline: ElAl
Departure Point: Rome   Destination: Tel Aviv
Outcome: Deplaned in Algiers
Terrorist Affiliation: PFLP

Incident Number 20.

Date: 30.1.71
Airline: Indian Airlines
Departure Point: Srinagar   Destination: Jammu
Outcome: Plane destroyed Lahore, Pakistan. Terrorists arrested.
Terrorist Affiliation: KLF

Incident Number 21.

Date: 21.5.76
Airline: PAL
Departure Point: Davao   Destination: Manila
Outcome: Plane stormed Zamboanga
Terrorist Affiliation: MNLF

Incident Number 22.

Date: 7.4.76
Airline: PAL
Departure Point: Cagayan do Ora Destination:Mactan
Outcome: Surrendered Benghazi. Libya
Terrorist Affiliation: MNLF

Incident Number 23.

Date: 1.1.70
Airline: Brazilian
Departure Point: Montevideo   Destination: Rio
Outcome: Deplaned Havana
Terrorist Affiliation: Var-Palmares

Incident Number 24.

Date:
Airline: Continental Airlines
Departure Point: Pheonix   Destination: El Paso
Outcome: Overpowered in El Paso
Terrorist Affiliation:None

Incident Number 25.

Date: 21.4 68
Airline: Delta Air
Departure Point: Chicago   Destination: Miami
Outcome: Deplaned Havana
Terrorist Affiliation: None ·

Incident Number 26.

Date: 9.9.70
Airline: BOAC
Departure Point: Bombay   Destination: London
Outcome: Hijackers deplaned Jordan. Plane was destroyed.
Terrorist Affiliation: PFLP

Incident Number 27.

Date: 22.7.70
Airline: Olympic Airways
Departure Point: Beirut   Destination: Athens
Outcome: Hijackers deplaned Cairo
Terrorist Affiliation: PPSF/PFLP ?

Incident Number 28.

Date: 22.2.72
Airline: Lufthansa
Departure Point:Hong Kong   Destination: Athens
Outcome: Surrendered Aden, South Yemen.
Terrorist Affiliation: PFLP ?

Incident Number 29.

Date: 8.5.72
Airline: Sabena Airlines
Departure Point: Vienna   Destination: Tel Aviv
Outcome: Stormed Tel Aviv
Terrorist Affiliation: Black September

Incident Number 30.

Date: 12.6.71
Airline: TWA
Departure Point: Chicago   Destination: New York
Outcome: Shoot Out.
Terrorist Affiliation: None.

CHAPTER 7: APPENDIX B

THE 29 VARIABLES USED FOR SSA

Twenty-nine Variables for Smallest Space Analysis.

Variable 1. US Plane

This variable indicates that the plane which was hijacked was owned by an American company.

Variable 2. Israeli Plane

This variable indicates that the plane taken over was El Al.

Variable 3. Japanese Plane

In these cases the plane which was hijacked belonged to a Japanese airline.

Variable 4. International Flight

The fourth variable indicates whether the flight was scheduled on an international or a domestic run.

Variable 5. Held-up Stewardess

This variable indicates the first move made by the terrorist/s. Those incidents in which the first move was reported as holding up the stewardess are coded 1 whilst those that were initiated through other or unreported means are coded 0.

Variable 6. Message Given to Passengers

Variable six refers to whether or not the hijackers gave a message of some kind to the passengers, whether reassuring or explanatory. Those cases where no message was given or no message reported score 0.

Variable 7. Polite

This variable refers to those instances in which the hijackers were particularly mentioned as being polite in their dealing with passengers or staff.

Variable 8. Radio Broadcast

In certain cases the hijackers themselves use the aircraft radio to broadcast a message of some kind to air traffic control to be passed on to another party. These are coded 1.

Variable 9. Damage to Plane

Incidents coded 1 on this variable refer to those cases where the hijackers cause deliberate damage to the plane, usually by blowing the evacuated plane up once landed at the intended destination.

Variable 10. Threat of Damage

Threat of damage refers to the variable above but in this instance the damage is not carried out.

Variable 11. Hostages

Variable 11 refers to the use of passengers as hostages other than on board the plane. In these cases, coded 1, once the plane is evacuated the hostages are taken to a further destination and kept as part of the negotiation process.

Variable 12. Guns

This variable simply refers to whether the terrorists were carrying guns.

Variable 13. Explosives

This variable indicates whether or not the terrorists had explosives with them.

Variable 14. Grenades

The next variable indicates whether the terrorists were reported as having grenades.

Variable 15. Swords

Whether the terrorists carried swords.

Variable 16. Personal Problems Discussed

A code of 1 on Variables sixteen indicates that the hijacker/s commented on their own personal situation in some way, discussing problems or feelings about themselves or their lives.

Variable 17. Suicidal

This variable indicates that the hijacker/s displayed a suicidal attitude with respect to their own personal fate, for example not caring if they are killed in storming the plane or mentioning suicide as a solution if the hijack was unsuccessful.

Variable 18. Martyrdom

In contrast this variable indicates that the hijacker/s would be prepared to die, but as part of the terrorist mission, suggesting that they blow up the plane with passengers and themselves on board for example.

Variable 19. Shots When Forced

This variable is used to indicate that the hijacker/s did actually fire shots during the incident, and that this was in response to some external action. For example, if an attempt was made to thwart the hijack.

Variable 20. Spontaneous Shots

Variable 20 on the other hand refers to those incidents in which shots were fired other than in response to something. These incidents involve shootings which rather than being defensive in response to non compliance are controlling or offensive, eg shooting a passenger.

Variable 21. Physical Restraint

In those cases coded 1 for physical restraint, the hijackers use some form of control over the passengers or crew which is of a physical nature, for example instructions to lie on the ground, or tying passengers.

Variable 22 Verbal Restraint

Variable 22 refers to control over passengers or crew which is verbal alone, involving instructions to limit their activities, for example instructions not to move.

Variable 23. Demoralisation

Demoralisation refers to nay type of behaviour initiated by the terrorists which are designed to demoralise passengers rather than simply to control their movements. An example would be of flashing lights on and off in order to stop people from sleeping during the night.

Variable 24. All Passengers Released

When the plane reaches its new destination, variable 24 indicates that the hijacker/s allow all the passengers to deplane.

Variable 25. Certain Passengers Released

In these cases, coded 1, only some of the passengers are allowed to leave the plane. This may be on the grounds of gender, nationality, or compassionate reasons eg ill health.

Variable 26. Motive Release

Variable 26 is the first of three variables which indicate the hijacker/s motivations for the hijack. The first of these is when the demands they make include the release of certain prisoners whether they are captured colleagues or political prisoners held somewhere.

Variable 27. Motive Relocation

In these cases the motivation of the hijack appears to be the simple transportation of the individual/s to another country for political or other reasons.

Variable 28. Motive Publicity

In these cases demands are made for messages to be published in newspapers, leaflets to be dropped, or announcements made to various organisations. This type of publicity is used with or without the motivation of release.

Variable 29. Negotiable

An incidents is coded negotiable (1) in cases where the hijackers back down on certain stipulations, eg when they are prepared to extend a deadline for their demands.

POSTSCRIPT

Developing the System

8.1. Three types of representation: An Integrated System.

To date the research has worked on developing two types of representational system for decision making, Multidimensional Scalogram Analysis (MSA), and Partial Order Scalogram Analysis (POSA). These two types of representation allow the comparison of similarities and differences between a number of instances, or decision options on a number of qualitative dimensions or facets.

The report has illustrated the potential importance of studying the relationship between the facets themselves. It has now been recognised that relationships between the facets have a role to play in the decision making process. For example, if two facets are being applied to the instances in a 'coherent' way, then they have related implications for the instances selected in the decision.

Whilst it is possible to examine the relationships between each of the facets from the way in which they function as regional structures in the MSA and POSA plots, there exists a programme which represents relationships between facets directly. Using this programme, known as Smallest Space Analysis (SSA), it is possible to represent each of the facets themselves as a point in geometric space, based on the similarities and differences in the way in which they have been used by the group members in classifying the instances; facets that are used in a similar way will be closer together in the plot.

In this way the overall relationship between the facets , now acting as variables in the analysis, can be examined. These configurations are themselves open to interpretation using facet theory, giving a range of possible structures which can be identified in the SSA plot, and which in turn have implications about the relationships between the variables (facets). The addition of this analysis technique will make it possible to have a hierarchical system of representations, whereby at the highest level, the superordinate structure of relationships between the facets can also be used to feed into the decision process.

Further research would allow the development of this third programme to the repertoire of representations for qualitative data. It is hypothesised that by representing the relationship between the facets themselves more directly at the outset of the decision making process, it will be possible to increase the scope of the decision support system.

Once the full range of representational systems are developed it will be possible to develop a fully integrated system of programmes which can be used in any situation where decision making is based on qualitative data. Each of the programmes relates to next in a logical sequence, examining the relationships between the decision options, or instances being considered by a group of experts. If the system were to be fully developed it would thus be possible to move through each stage depending on the nature of the problem being addressed. Each stage of the analysis would reveal different dimensions of the decision

options, including the relationship between instances on qualitative facets (MSA), a scaling of decision options or instances according to qualitatively different facets (POSA), and the overall relationship between the facets of the decision making process (SSA).

A schematic diagram which demonstrates the way in which these programmes may be developed to provide an integrated decision support system (Facet Analysis Decision Support System : FADS System) is shown in Figure 1.

8.2 A Three Stage System

There are three overlapping stages in the inference system.

Stage 1: The first stage allows the elicitation of decision options (entities) and the facets (attributes) considered to be important by the individual experts. Classification of the entities on each attribute produces a data matrix for analysis either on the individual level, or for all the members of the group. At this stage SSA can be used to clarify the facet structure used by the individual or the group and can be fed back to the elicitation phase for clarification or modification.

Stage 2: Once the salient facet (attributes) of the decision have been established, analysis using MSA or POSA can be used to represent the decision task, and with reference to decision making group, the group processes involved. In an interactive system this phase could include a feedback loop where the group can reassess the options and attributes (facets) restructuring the representation as part of the decision process.

Stage 3: On the basis of the interaction between the expert decision makers and the representational system a decision or selection of options can be made.

8.3 A Parallel System of Expertise

Whilst these three phases work as an integrated system for decision support, the research has highlighted the need for a parallel system of expertise, shown on the right hand side of Figure 1.

Research has shown that the selection of appropriate attributes for the analysis is crucial to accurate representation. This parallel system would allow results of the analysis of knowledge inherent in a data base to be accessible to the group at any stage during the decision making process.

In this way, for example, facets which have proved to be useful in distinguishing between criminal or terrorist incidents may be suggested for classification by the experts at the elicitation stage.

Further, the facet structures and their representation with respect to incidents within the data base may be examined for their implications to the current investigation. Thus the parallel system may be used by the group in reference to the current decision problem at any stage during the decision making process.

Figure 1
Schematic Diagram of FADS   System
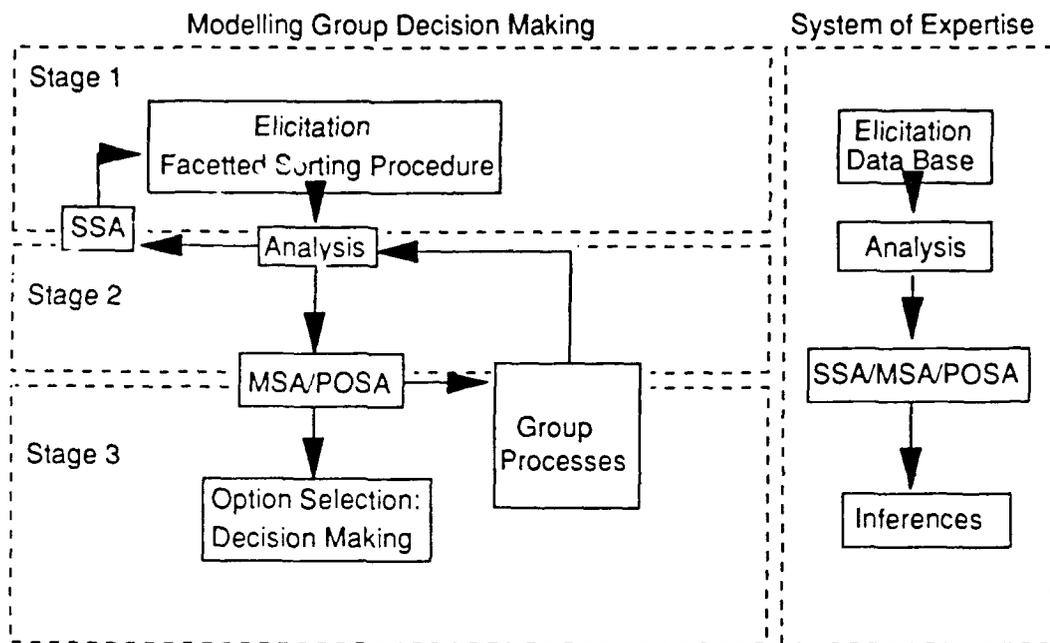
Stage 1: Establishing Facets and Options

Stage 2: Representation of Task and Group Process

Stage 3: Option Selection / Decision

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TECHNICAL APPENDICES
A Four Stage Theory of Inference Derivation

There follows an outline of the technical detail pertaining to the four stages of the inference system in order to provide a solid base for the interpretation of the results of the studies.

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┌─────────────────────────────────┐
│ 1.Knowledge Elicitation         │
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┌─────────────────────────────────┐
│ 2.Knowledge Representation       │
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┌─────────────────────────────────┐
│ 3.Inference Derivation          │
└─────────────────────────────────┘

┌─────────────────────────────────┐
│ 4.Decision Making               │
└─────────────────────────────────┘
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1. Knowledge Elicitation

i) Traditional Approaches

There are a variety of knowledge elicitation (KE) procedures which are used by knowledge engineers in extracting information from experts (Gammack 1987), with the aim of forming decision rules for expert knowledge. These processes have been developed within the context of expert systems and are therefore directed towards representation of the relationships between concepts in a given field.

Burton et al (1987) outline some of the elicitation techniques open to the knowledge engineer. One of the most frequently used techniques is protocol analysis. Using this technique, the knowledge engineer observes the expert actually doing his or her job. The draw back with this approach is that important pieces of the experts' knowledge may not be used on a day to day basis, and so the system derived would not contain certain important, but infrequently used aspects of the experts' knowledge. Forward Scenario Simulation on the other hand, allows the engineers to decide which aspects of the experts' knowledge they wish to access, and involves the expert verbalising the rationale behind their decisions made in response to preset hypothetical problems. However, one problem with this technique is that experts may not be able to verbalise their decision rules, or may be prone to post hoc justifications of their decision strategy, resulting in spurious decision rules being entered into the system.

Goal decomposition is the first of what Burton et al (1987) describe as the 'more contrived' KE techniques, and they describe two techniques, '20 questions' and 'laddered grid'. In the case of twenty questions, the expert is required to ask the engineer questions regarding a series of solved problems, in order to find out what the problem was. This procedure reveals the kind of information an expert needs in order to solve a problem, and the order in which the information is requested brings an insight into information processing. However, in order to use this technique, the engineer needs to know enough about the experts' field to construct the problems and to answer the questions. The second technique in this set is the laddered grid. This technique relies on starting the expert at a certain level on a 'conceptual ladder' and moving up and down the ladder to map out the hierarchical relationships between concepts within a field of expertise. In this way, one element of a concept can form a starting point from which other examples of that concept can be sought. Once examples have been given, the knowledge engineer can question the expert over the criteria that distinguish between the examples. This procedure can build up a picture of the concepts, their elements, and the hierarchical relationships between them.

A further set of KE techniques considered in the literature are those run by computer programmes themselves. Whilst the programmes allow experts to sit at a terminal and answer questions at their own pace, they are limited in their coverage of complex concepts.

The final class of KE techniques are multidimensional, and like the hierarchical and sequential techniques described above, provide the knowledge engineer with a map of the concepts within a domain. Using these techniques, however, has two major advantages; the relationships between the concepts do not have to be hierarchical, and need not be verbalised. The most commonly used technique in this class is the repertory grid. This procedure requires the expert to chose two elements of the content domain being studied which are alike in some way and a third which is different. The person is then required to label the dimension on which these distinctions have been made. However, in practical terms this procedure is very time consuming, and suffers from a number of methodological flaws (eg Brown et al 1976). An alternative way of eliciting similarities and differences for MDS is the card sorting technique which has a number of advantages. This procedure allows classification of the elements according to any and all of the criteria which the expert or experts believe to be important within the domain being studied.

Most of the traditional elicitation procedures are restricted in their application to more structured areas of expertise. For example, the laddered grid can only be effective when applied to an area of expertise which is rigidly hierarchical. Similarly, twenty questions assumes that decision making in an area of expertise follows a sequential pattern in its problem solving.

Therefore it is necessary to conclude that the success of different types of elicitation processes, is dependent on the type of knowledge being elicited. Burton et al (1987) have empirically tested the efficacy of various elicitation techniques in two different domains of expertise, (both of which were well structured). They conclude that whilst protocol analysis performs poorly in their elicitation tests, the more 'contrived' techniques such as laddered grids and card sorts are as valuable as the more traditionally favoured interviews. This finding was contrary to the views of the experts themselves who believed the

techniques to be the least successful (Schweickert et al 1987). They conclude that 'It appears that an expert's view of what constitutes a good KE session is not predictive of its real efficacy'.

Although Burton et al (1987) accept that different domains of knowledge may call for different types of elicitation, they also suggest that the personality or cognitive style of the experts themselves, eg introversion/extraversion and field dependence/independence may also call for different elicitation techniques.

Nevertheless, it is clear that elicitation techniques should be tailored to the knowledge area being studied and it is the less structured, open ended techniques which are required to access qualitative dimensions of expert knowledge. Three broad types of knowledge are considered within the current research. First, there is 'knowledge' which exists within a data base, derived from the underlying structure of the relationships within the data. The second type of knowledge is idiographic, that is the idiosyncratic view points of individuals. Finally, there is the shared knowledge of concepts which exist within a professional community or expert group. All these types of knowledge can be drawn upon to make decisions. The current research thus confronts all three levels of knowledge, using corresponding elicitation and representation procedures.

The chosen elicitation procedures are therefore discussed in more detail below. Firstly, a facetted sorting procedure to elicit knowledge from both individuals or groups; secondly the use of content analysis, in order to reveal the underlying structures in a data base, and therefore the relationships between various areas of content.

ii) Expert Knowledge: A Facetted Sorting Procedure

The facetted sorting procedure allows the expert to assess a number of instances according the facets which he or she considers important with respect to their area of knowledge or expertise.

In classifying a number of entities within their knowledge domain, the expert generates a facet, corresponding to the criteria they use to divide the entities. With each different set of classifications, a different facet considered to be important in the knowledge area is generated.

By classifying the entities, the expert not only defines the facet itself, but the categories generated represent the elements of that facet. Thus, each facet contains all the elements necessary to account for all the entities.

For example, given a set of entities which were people, a facet of 'sex' would contain the elements 'male' and 'female'. In this way two principles of defining facets can be upheld. Firstly, it is required that all the entities could be categorised according to the elements of the facet, for example, all the people are male or female. Secondly, it is required that the categories, (or elements of the facet) should be mutually exclusive, for example, none of the people are male and female.

The facetted sorting procedure therefore generates the facets of interest within the

knowledge area, and allows for the definition of the elements of each facet with respect to a number of entities.

The facetted sorting procedure used in the current research should be placed within the context of methodological debate within the social sciences. The procedure developed in response to a number of general research requirements, which are particularly pertinent to the use of this method for elicitation of expert knowledge.

a) Elicited vs Provided Constructs.

In a good deal of psychological research investigators have assessed people's thoughts and feelings on a various issues (their knowledge) using a number of structured techniques, eg the semantic differential, and the repertory grid. However, the major failing of these techniques lies in the use of 'provided' constructs (Stringer 1977; Wohlwill 1976; Canter et al 1985). By deciding which issues are important to the participants before they take part in the study, researchers are by passing the participants 'own knowledge' of the events, people or places, and imposing their own judgments of the things which are important to the population being studied.

The a priori judgments made by researchers regarding the factors important to an issue are often inaccurate, and this is particularly true when the field of enquiry is an area of expertise with which the researcher is unfamiliar. It follows then that when the research is directed specifically at issues of expert knowledge and the representation of group opinion, a methodology must be sought which focusses directly on the facets considered to be important by the individuals whose expertise is to be represented.

In contrast to earlier techniques the facetted sorting procedure provides the participants with a focus for the judgments to be made, yet allows their own decision facets to be elicited, placing the emphasis of the knowledge on those from whom it is being sought.

The sorting procedure was developed by Canter and his colleagues (eg. Canter et al 1985) as a research tool which would overcome the problems associated with repertory grids and semantic differential scales. Drawing on the ideology of Personal Construct Theory (Kelly 1955) the procedure emphasises people's own understanding of the world, and hence the use of elicited constructs or facets. Contemporary cognitive psychology points to the importance of categorization in human information processing (eg Rosch 1978), and the early sorting procedures used by clinical psychologists provided a methodological model.

b) Verbal and Non Verbal Facets of Knowledge

The traditional methods employed to measure people's thoughts,feelings or opinions in psychological research have suffered from a further problem. Techniques such as the interview, questionnaire or semantic differential scale rely on the individual being able to verbalise the knowledge they have, be that their own opinion on an issue, or their knowledge in an area of expertise. It has been suggested however, that there are certain aspects of people's knowledge or feelings about the world which cannot be verbalised, and eliciting a verbal label for a non verbal distinction can be meaningless, if not totally misleading.

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Using a sorting task for the elicitation of knowledge allows the use of both elicited constructs, and therefore the expert's own interpretation of the facets relevant to the issue. However, this procedure also allows for the derivation of facets which need not be verbalised by the individual. Further, it is possible to collate the information given by all members of an expert group, and reveal an underlying system of conceptualizations which may not be related to the experts' verbalised system of judgments at all (Wilson 1989). In this way, overt properties of the items in any facetted sorting procedure can indicate the basis of their association both dependently and independently of the verbal labels assigned to them.

c) The Elicitation Procedure

Broadly speaking, the 'Multiple Sorting Procedure' allows the identification of the key concepts (facets) which are central to a particular area of thought. In categorising a number of possible elements according to the facets of their choosing, the participants allow the development and analysis of the facets which are relevant to their perceptions within that domain.

Further, the relationships revealed between the elements of the facets, give a further insight into the underlying structure of the person's conceptualizations of a particular domain.

Participants are asked to familiarise themselves with a range of instances or elements, and to subsequently categorise them according to their own criteria. No limits are generally imposed upon the participants' categories, they are allowed as many or as few groups as they wish, and as many or as few representatives of each group as they wish. This differs to some other sorting procedures where participants are sometimes not only required to sort items according to the researcher's criteria but are also required to adhere to a strict distribution of elements. In the current example, the choice of facets, elements and instances are left to the person whose knowledge is sought.

However, the advantage of the facetted sorting procedure is that it allows people to access the main facets being used in their conceptions of a situation, knowledge area, or series of events, it can also be used with predetermined facets. In this case the participants would be presented with the main facets which have been developed to deal with a certain situation (eg facets of criminal behaviour), and then their expert interpretation of the way each element of those facets relates to a number of instances is then elicited.

For example, work by Canter and his colleagues has demonstrated the importance of certain major facets in distinguishing between perpetrators of sexual attacks. When confronted with a new set of crimes, it may be possible for relevant experts to use their knowledge to categorise each new incident according to the main facets, eg location, murder, theft.

iii) Data Structures: Content Analysis

Content analysis is used to identify the underlying facets of 'knowledge' which are inherent within a data base. In the present research, content analysis of witness statements and other qualitative police material is used to identify facets of criminal behaviour which can be used to distinguish between the perpetrators of sexual attacks.

A number of testable facets of criminal behaviour have been established (see section 3) using Content Analysis teamed with Multidimensional Scalogram Analysis. Like the facetted sorting procedure, the literature can be addressed in order to outline the basic principles of content analysis. Mostyn (1985) outlines the primary aims of Content Analysis,

'Content analysis is the diagnostic tool of qualitative researchers which they use when faced with a mass of open ended material to make sense of. The overall purpose of the content analysis approach is to identify specific characteristics of communications systematically and objectively in order to convert the raw material into scientific data' (Mostyn 1985 p117)

In terms of the actual process involved in content analyzing the descriptive data, the researcher examines the raw material and searches for any consistencies in the themes or concepts which are represented. However, in order to assess the reliability of the researcher's interpretation of the material, it is necessary for the process to be repeated by one or more analysts, as described by Bainbridge (1985).

'First several judges independently develop a set of categories. Then they attempt to use each others categorization schemes. This both pools the inferences the judges have made about the important distinctions to make in analyzing the material, and also tests whether different people can repeatedly make the same allocation of material to the categories. If not, then an analysis using these categories cannot give reliable data and must be revised, again with the judges working independently during development, and coming together for assessment.' (Bainbridge 1985 p207)

However, as Krippendorf (1980) has noted, content analysis is not a simple matter of extracting the 'content' from the data as if it were contained within it, nor does it 'denote nothing more than counting qualities (words, attributes, colours)' (Krippendorf 1980 p22)

In analyzing the content of raw material it is necessary for the researcher to impose some interpretation of the content as a reflection of deeper phenomenon. Indeed, Mostyn (1985) lays out the stages of content analysis in the form of hypothesis generation and testing. The researcher sets up the conceptual categories for the content analysis on the grounds of testable hypotheses. This is followed by reformulation of the theory on the grounds of the relationships found amongst the data.

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In 'eliciting' facets of knowledge from a data base in this way it is possible to build up a picture of the inter-relationships of the facets with the data,and to draw inferences based on both the relationships between facets themselves, and the similarities and differences between the elements of the data base when assessed on each of these variables.

2 Knowledge Representation

The necessary relationship between types of knowledge and elicitation procedures used has been discussed in section 1. However it is also necessary to select a corresponding method of knowledge representation which is suitable to the type of knowledge sought and which is directly applicable to the structure of the knowledge generated through the elicitation procedures. For example, knowledge which is sequential or hierarchical, can be elicited through the laddered grid or twenty questions procedure, and represented using decision trees or semantic networks. Other types of representation suitable for structured area of knowledge include diagrams of various sorts (eg circuit diagrams) systemic grammar networks, 'semantic nets', influence diagrams etc.

However, many areas of expert knowledge are not amenable to such structuring, being non sequential, qualitative, and multidimensional.

Representation of qualitative data has been considered a problem for researchers in the past. Brenner et al (1985) go as far as to say that the study of qualitative issues in psychological research have been avoided by researchers, who have been unsure as to how to handle the data. The two knowledge elicitation procedures discussed above, content analysis and the facetted sorting procedure, are both capable of generating purely qualitative data, and it is the 'new' procedures for dealing with large quantities of qualitative data which can be drawn upon to structure these complex relationships.

Various forms of multidimensional scaling (MDS) have been proposed to reveal the structure of complex psychological relationships. Forgas (1979) believes that by using MDS procedures psychologists will be able to 'quantify and describe extremely complex psychological phenomena which would not be accessible to quantitative analysis otherwise.' (Forgas 1979 p253)

It is precisely this ability to structure the complex relationships between qualitatively different entities which makes multidimensional scaling ideal for representing the underlying basis of most real decision making tasks.

The main concept involved in the use of MDS procedures in the elucidation of complex relationships, is the ability to represent psychological distances or similarities, in terms of physical distances in geometric space. In this way MDS allows examination of the structure of various psychological concepts, using physical representation of distances between items as representative of the psychological relationship between the entities.

When dealing with multi attribute qualitative data such as that found in police investigations, it is necessary to portray the qualitative distinctions between a number of instances (eg Doignan and Falmagne 1985, Young 1988).

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The present research explores the possible use of Multidimensional Scalogram Analysis (MSA) and Partial Order Scalogram Analysis (POSA) to deal with categorical qualitative data, and ordered qualitative data respectively. MSA will be used to to represent different experts' views, as a possible decision support system. Using such a representation will allow a group perspective based on both the individual's and the group's collective view of the decision problem.

Multidimensional Scaling techniques have been used as part of the knowledge engineer's repertiore of techniques for 'Intermediate Representation'. Intermeditate representation refers to the stage following knowledge elicitation in the construction of expert systems. This representation is used to structure the knowledge within an expert domain before it is converted to a computer based system.

Expert 1

Expert 2   Knowledge ---> Intermediate -------> Expert System
                                    Representation
Expert 3

Whilst a good expert system utilises the knowledge of many experts as an input to the system, the resulting expert system aims to contain only one perspective on the knowledge, the 'right' one (see diagram above).

The view of knowledge taken by the present research is focussed on knowledge which must be established within a group of experts. If a representation is to suceed in the context of decision support, then it must not only be based on a number of experts' views, but the resulting representation must reflect not only the composite group knowledge, but also the individual group member's component knowledge (see diagram below).

                                            Group
Expert 1
                                            ┌──────────┐
                                            │ Expert 1 │
Expert 2   Knowledge ----> Intermediate --------> │ Expert 2 │
                                    Representation   │ Expert 3 │
Expert 3   └──────────┘
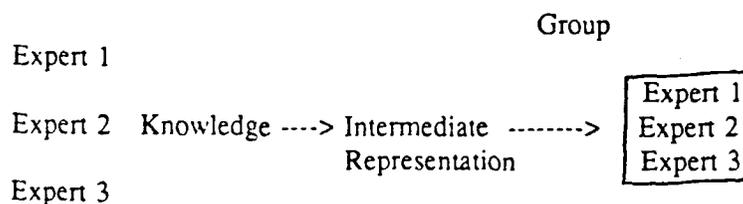
The following sections examine the representational techniques employed in the current research in more detail.

i) Types of Representation

As discussed above, a number of different types of multidimensional scaling procedures can be used to represent the structure of expert knowledge. Multidimensional scaling is a class of techniques, which all use the associations between a variety of objects as the input

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(that is the similarities between the objects) and the output is a spatial representation consisting of a geometrical configuration of points corresponding to the objects.

The two procedures selected for the present research are discussed separately below.

a) Multidimensional Scalogram Analysis (MSA)

Multidimensional Scalogram Analysis (Lingoes 1973; Zvulun 1978) is particularly suitable for the analysis of categorical data such as that generated by the facetted sorting procedure since it,

'deals with each response as a categorical one comparing the categories with each other. No order is assumed between the various categories, nor is any similarity of meaning assigned to the categories for each of the variables' (Canter et al 1985 p97-98)

In order to carry out MSA on data derived from a facetted sorting procedure, each individual's classifications of the instances within the domain are coded with a number to represent each of the expert's categories. These numbers comprise the cells of the data matrix. Therefore, each of the instances or entities selected for the sorting procedure is represented by a 'profile' of scores which indicates the categories to which it was assigned by each of the experts whose knowledge is sought.

The data matrix would thus be;

Experts (People P)

	P1	P2	P3	Pn
Entities (E)				
E1	1	4	3	2
E2	2	3	1	4
E3	4	3	2	1
En	1	2	3	4

In this case the cells of the matrix would correspond to the category to which each expert assigned each entity.

MSA analyses this categorical data produced by the participants in the facetted sorting procedure, and plots the items sorted in geometric space in such a way that the best possible fit between participant's categories and their representation as regions in the space is achieved. In effect this means that those items which are frequently placed in the same groups, regardless of the verbal rationale will be plotted closer together in the space, and those between which few similarities are drawn will be further apart.

Data derived from content analysis would be similarly structured. In this case each entity would be represented by a profile of scores on a number of variables or attributes derived from content analysis. The cells of matrix below contain numbers corresponding to the

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categories associated with each attribute (or facet of behaviour).

Attributes (A)

```
              A1  A2  A3 ..... An
Entities (E)
       E1     1   4   3      2
       E2     2   3   1      4
       E3     4   3   2      1
       En     1   2   3      4
```

According to the same principle, MSA on content analysed data will plot each entity in geometric space in an attempt to form regions which correspond to each category on each of the attributes. Thus, the more similar the entities with respect to the attributes on which they are described, the closer together they will be represented in the space.

In both these examples the programme provides 'item plots' which demonstrate the configuration of plots (entities) coded according to their classificatory scores for each of the people (P) or attributes (A). It is these individual facets and the relationship between them which can be used to draw conclusions regarding the entities themselves.

b) Partial Order Scalogram Analysis (POSA)

Partial Order Scalogram Analysis has been the focus of exploratory research for hypothetical decision making analysis in the interim report. Although POSA has not been formally tested in the research so far, developments have been made in the theoretical application of this method, and from our preliminary investigations we believe that this scaling technique holds considerable potential for use in the inferencing system.

Pilot demonstrations in medical decision making situations have received much positive feedback. The potential of POSA for future applications calls for an account of this method to be included in the current report.

One property of POSA which complements MSA is its special emphasis on ordered qualitative data. Whilst qualitative differences are represented in one dimension, the can be simultaneously considered in relation to quantitative variations within each facet (be that an expert's opinion, or an attribute of the data).

Therefore POSA deals with profiles of scores for each entity which can be characterised both qualitatively and quantitatively.
Firstly they can be thought in quantitative terms, ie the sum of the scores across the row. In a matrix (ExP) such a measure would indicate the experts' overall response to each entity as a group, a high total indicating a positive response on their ordered dimensions and a low total indicating a poorer opinion overall. This is thus a measure of the feelings of the experts as a group.

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In terms of the POSA plots, these quantitative similarities and differences are represented by the position of the points along the x+y or 'joint' axis of the POSA plot. Figure 1 shows a set of example profiles which systematically vary on the quantitative scale, and are thus plotted along the x+y axis.
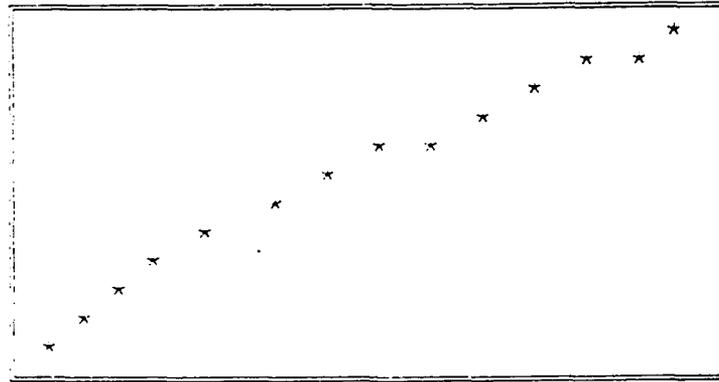
Figure 1. Sketch diagram of a POSA plotting quantitatively different profiles.

The second criteria which distinguish between the projects is plotted on the lateral, or x-y axis.

An example of such a plot is shown in Figure 2. This configuration would represent a set of profiles which did not vary much quantitatively, ie the sum of the profiles were the same, but did vary qualitatively. This qualitative variation is a result of experts' differing opinions of the entities.
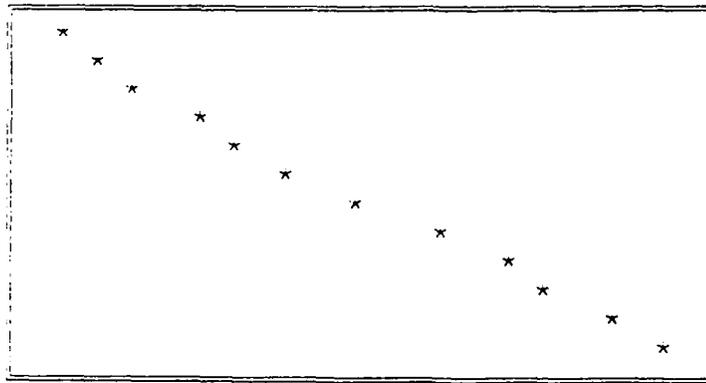
Figure 2. Sketch diagram of a POSA plotting qualitatively different profiles.

Lack of variation on the x-y or lateral axis thus indicates agreement between experts. On the other hand, the configuration of points shown in Figure 2 would suggest that the group as a whole feel the same way about all of the entities on the quantitative dimension, when the opinions of the individuals who comprise the group are taken into account the variations in their judgements are revealed. In a situation such as this the decision making process would be extremely difficult, since no real consensus exists between the experts.

It is particularly important to address the issue of qualitative variation. Whilst the sum total of each of the experts' opinions may be representative of the group as a whole, it does not represent the views of the individual members. If consensus was required within a decision making group, the subtle differences in opinion of the group members would be of prime importance to the decision making process. It is this quality of POSA which we believe holds so much potential.

ii) Types of Interpretation

The procedures used in the research so far carry with them a theoretical underpinning which suggests that the most fruitful way of interpretting the space is in terms of regions. This approach has been the one adopted so far when explanations have been given to the participants as to how the plots should be, or should have been used. Such a regional interpretation however, is only one of the broad modelling approaches that have been applied to matrixes of association. Although mathematically, the various approaches can be transformed into each other it is our hypothesis that some forms of representation will facilitate inference derivation and group decision making better than others.

Each approach to the modelling of relationships carries with it different assumptions about the nature of the models being developed. So the form and the flexibility of the inferences will differs from one to the other. Future research will explore these important issues, but

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for clarification, the three approaches envisaged will be summarised here.

Regions

Regional interpretations of multi-dimensional data are directly analogous to such interpretation in geography. They assume that the interpretation indicates a correspondence between aspects (facets) of relevance to categorising the observations and the spatial distribution that represents those facets. Therefore data points that have similar facet definitions (whether established a priori or post hoc) will be in a contiguous region of the space if those hypothesised facets do play a role in the data.

This approach makes no assumptions about the shapes of the contiguous regions or their relationships to each other. It also gives no special weight to absolute distance in the spatial representation. Items close in the space may be in different regions, just as the sea lapping on the shore produces a clear demarcation on a map between water and land.

Dimensions

```
                                    | Dangerous      *
                                    |                    *
                  *    *            |
                           *        |                *
                               *    |        *
                         *          |
      Haphazard─────────────────────┼────────────────────Well Organised
                                    |        *
                                    |            *
                                    |
                                    |
                                    | Safe
```
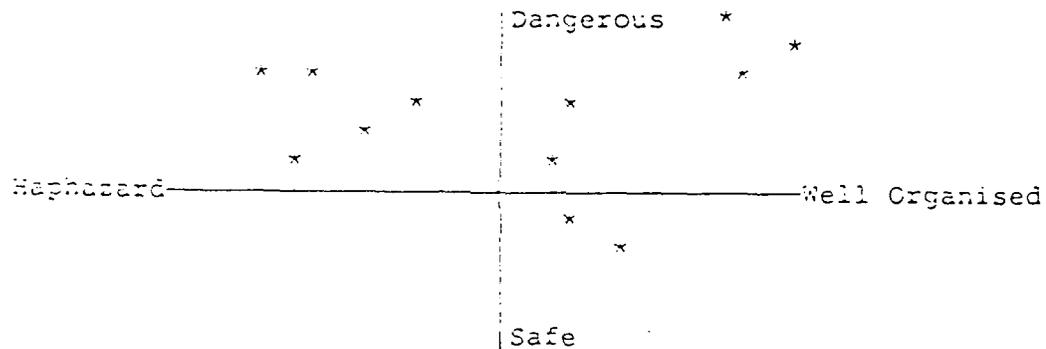
Dimensional interpretations assume that the underlying explanatory facets are continuous, linear and, usually, independent of each other. Each data point therefore is defined by its numeric combination of the properties inherent in the determined dimensions. In practice the dimensions usually have to be defined by those items that are high on one dimension but low on the others. This not only gives great weight in interpretation to extreme cases, but it does not usually allow emphasis to be given to those properties common to the observations, as they will have moderately high loadings on all dimensions, being in the centre of the plot.

Its advantage is that if dimensions are established they can be treated as powerful underlying continua upon which mathematical models can be based. Clearly, in the realms of qualitative data on which the current project is focused, very strong assumptions

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have to be made about the relationships between the original qualities and the new found dimensions.

Clusters
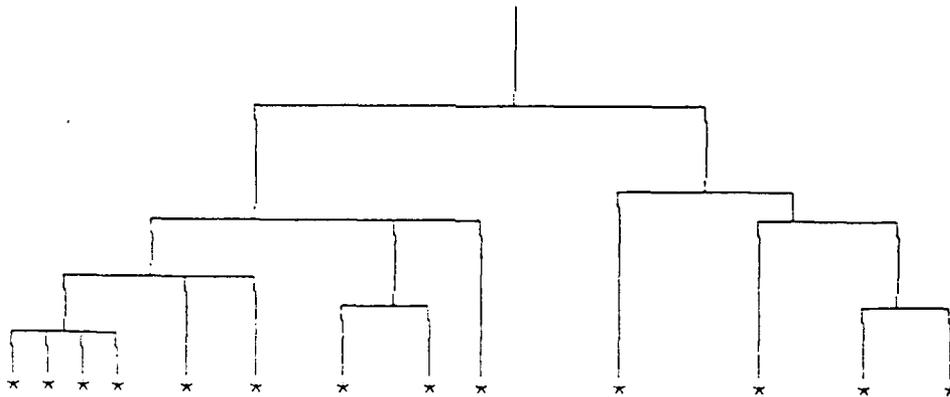
The principle assumption of clustering is that each individual can be assigned to one group on the basis that it has higher multidimensional relationships, on average, with all the individual's in that group than with the remainder of the population under study. Some approaches do allow multiple group membership but representation of this beyond three or more groups per individual become problematic. The criteria for relationship is mathematically arbitrary because at very low levels of the criteria every individual is related to every other, so there is only one global cluster, at very high levels of the criteria every individual is unique so each forms its own cluster. As a consequence clustering procedures are always, implicitly at least, hierarchical. They therefore assume that the underlying concepts contain a hierarchical relationship to each other.

This makes interpretation extremely difficult unless there is a very strong theoretical model that allows the specification of distinct point in the hierarchy, as for example in the Darwinian classification of the species on an evolutionary basis. To avoid this demand on such strong theoretical models a cut off point is usually selected, using inferential statistical models for example, and the clusters that occur at that point are used for interpretative purposes. No substantive theory exists, however, to indicate which cut-off points are appropriate for inferences from qualitative data.

Partially Ordered Systems

Although firmly within the facet approach of regional interpretation they recently developed partial order analysis, discussed in the interim report does combine some of the useful qualities of the dimensional approach as well. By drawing upon common order in the data it allows non-arbitrary dimensions to be established which are a direct products of the common order. It also allows the exploration of whether substantive variables, external to the analysis, do create clusters that are consonant with the structure that generates the partial order. For those decision problems in which a common order amongst the variables can be established a priori this approach holds great potential and is therefore included within our current and planned research programme.

Although only regions have so far been used in the research, further work will be directed towards a test of different types of interpretation to assess the ease with which they are assimilated by non experts for use within the inference system.

In particular in might prove valuable in clarifying the implications of regional interpretations to contrast them with dimensional and clustering interpretations of the MDS displays.

iii) Levels of Interpretation

Whilst each of these types of interpretation can be manipulated in order to see which one facilitates people's use of the method, the level of the interpretation should also be tested.

For example, using the regional interpretations tested so far, a number of levels of interpretation can be presented to the user.

a) Minimum Interpretation

At the least interpreted stage the user can be presented with the plots and given a brief description of the basic principles, eg closer together the points the more similar the entities, and an explanation of the use of item plots to represent the categories assigned to each entity on each attribute.

The research reported so far has worked at this level. This strategy was selected to enable the kind of information required by the participants to be revealed, and to assess the way the plots may be used by non expert groups.

b) Maximum Interpretation

At the opposite extreme, however, the most sophisticated level of interpretation which could be presented, would be representation with the regions superimposed on the plots, labelled, and shaded in such a way that regions can be compared with no prior work from the participants themselves. Work so far suggests that this highly interpreted level will indeed be necessary for naive users and has gone some way to detailing the most readily usable forms of interpretation at a visual level.

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3 Inference Derivation

Central to the development of the inference system it has been the examination of the way in which the spatial output of multidimensional scalogram analysis (MSA) can be used to draw inferences.

The following section details four possible types of inference which can be derived from the facets (variables or attributes) which form the input to MSA.

Examples are derived from expert interpretation of MSA plots with the aim of providing a first step towards systematising the use of MSA for inference derivation. However, the inferences examined apply equally to the use of MSA in revealing underlying structure of relationships in a data base, as to the use of MSA for inference derivation in group decision making.

The facet structure reflected in each item plot, for each attribute, plays a role in the overall configuration produced by MSA. The first type of inference is based on whether the structure of the facet represented in each item plot plays a role in the overall structure of the MSA.

The second type of inference which can be drawn from the MSA plot applies to the relationships between the entities. This type of inference concerns the 'population' of items being classified.

The structure in each item plot can be compared with the other facets in the data and used to derive inferences about the relationships between the facets themselves. A number of possible types of combination of facets can be used to interpret the underlying structure of the data relationships, and two types of combination of facets, coherent and independent, are illustrated below.

The final type of inference is drawn from the completed interpretation of the MSA structure, taking all the facets into account. These inferences are extrapolated from the overall facet model generated by the MSA.

These illustrations have been drawn from issues that emerged during the pilot work with naive users although they are also widely used by facet researchers. Such an exposition is intended to illustrate some of the principles for drawing inferences from MSA, and to show the potential for building up a picture of the relationships between various attributes associated with a number of entities.

While such an inference process is used, and therefore 'known' within a group of expert users, no previous attempt to systematise these 'interpretative rules' has been made.

This first set of instances of 'rules' have yet to be fed back to the experts and represent a first tentative attempt to document a subset of the many inference processes being used.

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Four Types of Inference.

1) Contribution of a Facet to the MSA Structure.

The first type of inference which can be drawn from the MSA output is whether or not a facet is supported in the MSA structure.

If the MSA plot can be divided into regions of entities which are associated with each of the elements of the facet, then the facet can be said to play a role in the overall structure. If however, entities associated with each element of the facet cannot be partitioned into regions, then the role played by that facet is not important to the overall structure.

2) The Relationship Between the Entities.

Two types of facet will initially be used to illustrate the inferences which can be derived about the relationship between the entities; simply ordered, and non simply ordered facets, shown in Figure 3 below.
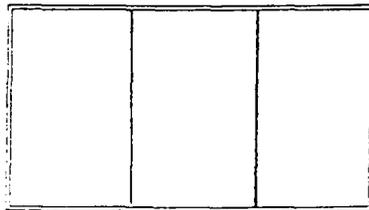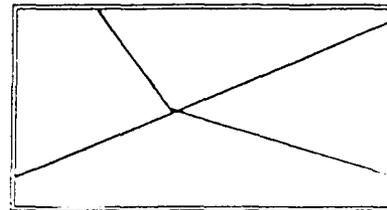
Simply Ordered Facet   Non Simply Ordered Facet

Figure 3. Sketch Diagram of Simply and Non Simply Ordered Facets.

In each item plot the facet can be seen the divide the population of entities in a number of ways. The way in which the facet divides the plot reflects the relationships between the entities on that particular dimension or criteria.

A facet which is simply ordered, implies that the entities possess increasing or decreasing 'amounts' of that attribute, as they are positioning along a certain dimension in the plot.

For example, if the entities in the plot were crimes, a simply ordered facet of violence would indicate that the incidents in one region were more (or less) violent than the incidents in the region adjacent to it.

If a facet is non simply order with respect to a set of entities it indicates that the relationship between the entities does contain an order, however, that order does not have simple end points. In this case the regions in the plot are ordered around the plot and

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imply that each set of entities around the plot are related to those in the adjacent region .n a circular order.

3) The Relationship Between the Facets.

Comparison the facet structure reflected in pairs of item plots can allow inferences to be derived about the relationship between two facets. Two such relationships are illustrated below, coherent and independent facets.

The MSA examples shown below are derived from an analysis of a set of eighteen crimes, committed by six rapists known to attack indoors. Each point represents an attack, and the two plots represent the configuration of the MSA plot interpreted according to two of the ten variables or attributes which were used in the analysis.

i) Coherent Facets

A pair of facets which are ordered and coherent, divide the plot into regions according to a broadly similar order.

Two types of coherent facets can be identified, distinguishable by the content of the facets, ie their meaning. If the two facets are comparable in the direction of the order, then more of

Figure 4. Two Example Item Plots showing the Facets of 'Violence for Control', and 'Violence other than for Control' for a sample of eighteen sexual attacks.

attribute x is associated with more of attribute y. Conversely, two facets may be coherently ordered, yet the meaning of those ordered is reversed. For example, more of attribute x may be associated with less of attribute y.

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The first example shows two item plots from the MSA on eighteen sexual attacks committed by known offenders. The stars in the plots represent the eighteen criminal incidents, and the two example variables can be superimposed onto the configuration to show which attacks were associated with which attributes (variables). When such plots are produced by the MSA, the points in the item plots are coded with a number to represent the classification of each entity on a particular attribute. In this way it is possible to define the regions, to enclose all the entities which have the same categorization on each attribute.

An example of two coherent facets is shown in Figure 4 above. In the first plot, 'violence for control' divides the attacks according to an order. This variable indicates that an attack can be described as having a quantitative amount of violence to control the victim, a little or a lot. Similarly, the attack may be characterised as having displayed a little or a lot of violence which was not associated with control. These two facets are coherently ordered and therefore suggest that there is a direct relationship between the two facets of violence.

ii) Independent Facets

'Violence for Control'   'Torn Clothing'
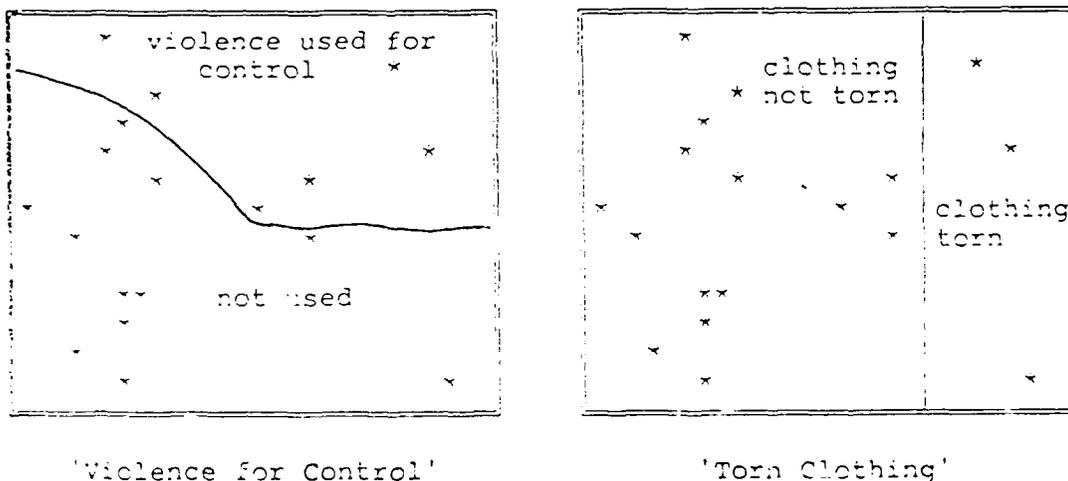
Figure 5. Two Example Item Plots showing the Facets of 'Violence for Control', and 'Torn Clothing' for a sample of eighteen sexual attacks

An example of two independent facets is shown in Figure 5. The MSA on eighteen sexual attacks drawn from the data base shows that the facets of 'violence for control' and the 'tearing of clothing' are independent.

This shows that all the combinations of the categories of these two variables are represented within the sample. In these cases it may be enlightening to consider the percentage of incidents which fall into each of the categories, to make inferences about the relationship between the two facets.

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4) Extrapolation from the Facet Model.

The final type of inference can only be drawn from the complete interpretation of the MSA structure, ie the Facet Model. Once the relationship between the facets and the entities has been established it is possible to extrapolate from the overall facet model to make inferences about attacks in general. For example, once a typology of offenses has been built up, then the quality of the offenses which are 'missing' in an empty space in the plot can be defined by reference to the facets which define the attacks which are present. Thus, once the facet model is complete, areas of the space which do not contain incidents can be as revealing as those that do.

Summary

The four types of inference discussed above represent a first stage in systematising the inference process using MSA.

Examination of the relationships between various facets can build up a typology of offenses and will allow various aspects of attacks to be associated with types of attacker. This will eventually have the potential for predicting qualities of the offender from known qualities of the offense.

Further, whilst documentation of the types of inferences derived from MSA is only in an early stage, once tested and expanded it form a valuable link in applying the inference system in decision making groups.

4 Group Decision Making

As the research has developed it has become clear that an emphasis must be placed on the group context of inference derivation. Many of the complex qualitative decisions considered take place within a group decision making context.

In order for the inference system to be applied to real decision making , the work must acknowledge that decisions are made within a complex psychological framework, and the effect which these variables have on the decision must also be considered.

The research has thus stressed that in order to construct a system that will work for group decision making it is necessary to address the connection between the dynamics of the group per se and the influence which the characteristics of the group have on the inferences drawn, and the ultimate decisions made.

It is therefore essential that the elicitation and representation techniques be anchored to group processes, since each expert's knowledge is extracted, represented, and then applied within a social context in the derivation of inferences and decision making. Elicitation is thus part of the group process. Rather than accessing finite 'pieces' of knowledge, elicitation is an interactive process, through which each member's perceptions inevitably effect other members', and thus the group's eventual decisions.

Similarly, a number of other facets of the group's psychological structure can also be expected to have an impact on the decision.

Many researchers have investigated the link between aspects of the groups' structure, such as cohesion and leadership style, and the resulting decision making process.

For example, Janis (1982) has characterised a number of aspects of group structure, the most prominent being 'cohesion', which he believes to be determinant of 'groupthink', a phenomenon in which group members behave in a particular way in order to conform to the groups' collective view, for example accepting poor solutions on predetermined criteria, and discarding plausible alternatives at an early stage. On the other hand cohesive groups engender greater participation and loyalty amongst their members and a greater desire to conform to group standards (Swap 1984).

Communication structure within decision making groups have also been the focus of much research. Central involvement in the communication structure results in group members' increased satisfaction with their role (Cartwright and Zander 1968), and perception of leadership from the other group members. The network of communication within the group has also been related to the efficiency of the group in accomplishing various tasks.

The style of leadership within a group has also been thought to influence aspects of the groups' behaviour. Lewin's pioneering work in characterising democratic, autocratic, and laisser-faire leaders did much to demonstrate the scope of the influence of leadership style.

Fiedler (1967) has assessed the impact of leadership style in terms of the interaction between the personal characteristic of a leader and the situational characteristics of their position. His work has shown that leaders who are oriented towards the 'task' or 'relationships' in the decision making group are successful in different situations, dependent on a number of factors inherent within the group.

Because of these processes, any representational system has to connect with group dynamics. Factors such as cohesion, communication and leadership are issues to be addressed in the future development of the research, in order to assess the interaction between factors of the group structure and the scope for intermediate representations as a decision making aid.

For example, MSA enables each group members' assessment of the situation to be represented and discussed within the group. Although this procedure implies a democratic group with an open communication structure, the extent to which these individual representations are taken on board by the group as a whole may well relate to variables such as status and leadership within the group.

In every group interaction there are stages which can be characterised as 'goal oriented' (directed towards the task in hand) and 'process oriented' (directed toward the establishment of group structure). These aspects of the groups' behaviour can be addressed by different aspects of the representational capability.

For process oriented intervention, the representational techniques allow analysis of people's differing opinions and may provide a solution to establishing agreement and

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loyalty. On the other hand, groups directed towards the content of the task in hand will also find the representations a very valuable tool demonstrating the complex relationships amongst qualitatively different solutions. Both representational techniques allow for the input of all the members of the team, and structure not only the content of the decision domain (goals) but also the structure of the decision group (eg alliances, disagreements).

Work has been done to develop a reliable instrument for measuring aspects of the group members' response to the group decision making exercise, both in terms of the task and the process variables of the event.

This pilot questionnaire represents the first stages in gaining feedback from the group members which can be used to assess the impact of the representational system. This instrument will allow future work to be assessed so that improvements in cohesion, communication, problem structure and focus can be gauged in experimental comparisons of qualitative group decision making both using and not using the inference derivation system.